FIRST BOOKS OF TECHNOLOGY

CARPENTRY AND JOINERY

F. C. WEBBER

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TEXT-BOOKS OF TECHNOLOGY

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CARPENTRY AND JOINERY

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BY

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WITH 176 ILLUSTRATIONS

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PREFACE

THE substance of the present volume was primarily compiled for the use of students attending the evening classes in Carpentry and Joinery at the Merchant Venturers' Technical College, Bristol.

The Drawings, which have been specially prepared by the author for this work, are intended to serve not only as illustrations to the text, but as examples for reproduction by the student, so that he may be in a position both to execute a piece of work himself, and, as foreman or leading hand, to convey readily his idea of the form or outline of such work to others.

The author has ventured to place the work in its present form in the hands of the public, with a hope that it may be found useful not only to students preparing for the examinations of the City and Guilds of London Institute and other similar bodies, but as a work of reference for the apprentice and craftsman generally.

FREDERICK C. WEBBER

MERCHANT VENTURERS'
TECHNICAL COLLEGE
BRISTOL

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CHAPTER I.

INTRODUCTION.

Drawing Instruments.—It is advisable that the student should obtain at least the following instruments and material of moderately good quality.

Drawing Paper.—For students' work a fairly good cartridge paper at about 2d. per imperial sheet is as good as will be required, but where the paper is to be subjected to hard wear, as in the workshop, a good hand-made paper should be used. The cost of the latter will be about three times that of the former.

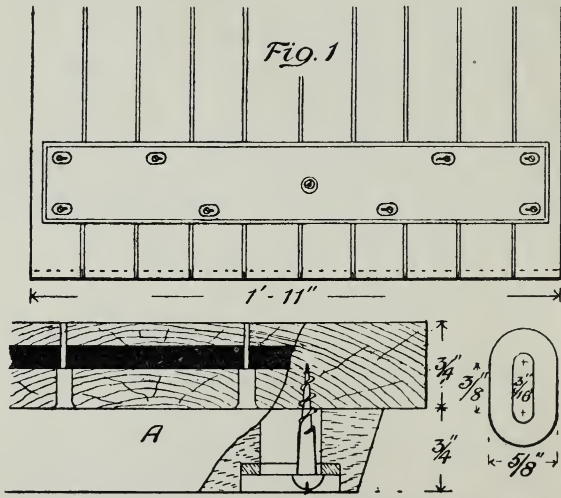
The following is a list of names and sizes usually placed upon the market:

Name of Paper.	Size.
Demy, - - -	20 in. by 15 in.
Medium, - - -	22 in. by 17 in.
Royal, - - -	24 in. by 19 in.
Imperial, - - -	30 in. by 22 in.
Atlas, - - -	34 in. by 26 in.
Double Elephant, - -	40 in. by 27 in.
Antiquarian, - -	52 in. by 31 in.

Cartridge paper and tracing paper may also be obtained in rolls. The most convenient form for the

present work will be the imperial sheet cut in two, so that its dimensions are 22 in. by 15 in.

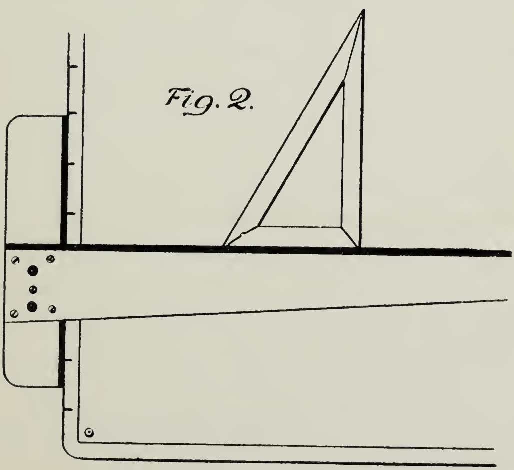
Drawing-Boards.—Whatever the size of paper used, the drawing-board should be in its linear dimensions one inch larger, the half-imperial board would then measure 23 in. by 16 in. It should be true in plane and free from knots and shakes, and should be so constructed as to be free to expand and shrink with the changes of the atmosphere without buckling or twisting. Drawing-boards usually sold are of lime or yellow pine, but the latter will be found to be the most serviceable, as the drawing-pin is more easily pressed into its surface.



The best boards are made of well-seasoned material, and as shown in Fig. 1. The ledges on the back of the board are fastened by means of rose-headed screws, provided with brass washers which, with the exception of the centre one, are slotted, as shown at Fig. 1. By

this arrangement the plane of the board is kept true, whilst the expansion and contraction of the material is not hindered. If the board is grooved upon its back, as shown in the previous sketch, not only is the weight reduced, but the bulk of the material being lessened, the tendency to expansion and contraction is also reduced. These grooves may be made about 2 in. apart, $\frac{1}{4}$ in. wide, and to a depth equal to half the thickness of the board. The thick black line at *A* represents a tongue of hard wood glued into the left-hand edge of board, so that the tee-square may slide easily upon that edge. This tongue is also cut through at intervals to allow for the changes due to the alteration in the amount of moisture contained in the atmosphere.

Tee-Squares.—Of these, there are two forms:



one having a parallel blade, whilst that of the other tapers from the stock, and, being lighter to handle, is

to be preferred to the former. Fig. 2 illustrates such a one, its two fiducial edges being protected with hard-wood slips bevelled towards the paper. The blade is fastened to the stock by means of five screws, and, in order to secure its rigidity, two small hard-wood plugs are driven through the blade and into the stock.

The tee-square should only be applied to the left-hand edge of the board, and all horizontal lines should be drawn from its top edge. Perpendicular lines are drawn by the aid of the set-squares applied to the top edge of the blade of the square, as shown at Fig. 2.

Set-Squares.—Two of these, at least, should be obtained—one 30° and 60°, and the other 45°—and, if of wood, should be of the framed variety. They should be of such a size that the longest edge is at least eight or nine inches long.

Scale-Rules.—In the earlier stages of the student's career it will be advisable to adopt the simpler scales, such as $\frac{1}{2}$, $\frac{1}{3}$, $\frac{1}{4}$, and $\frac{1}{8}$, when the detail is too large to be plotted full size. In each of these cases the ordinary joiners' rule will be found to be sufficient, but as he progresses other scales are necessary, and for these the "Architects' Scale Rule" may be used; it is of box-wood and 12 in. long, segmental in section, and with its edges parallel, sixteen scales are marked upon its surfaces, and, with a slight exception, the divisions are brought out to the keen edge, so that dimensions may be plotted directly upon the paper without liability to error.

Parallel Rules.—These are usually unreliable, unless of the kind known as "perpetual." The student will

find that parallel lines drawn by the aid of set-squares, as shown at Fig. 3, will be the most accurate.

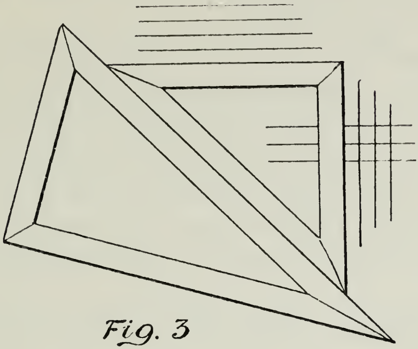


Fig. 3

Pencils.—The best pencils for work of this kind will be found to be those marked H or HH, sharpened in the form of a wedge or chisel-point. When a drawing is to be finished in pencil it will be advisable to take a finely-pointed HB and "line over" those lines which border surfaces at the bottom and to the right, as shown at Fig. 4.

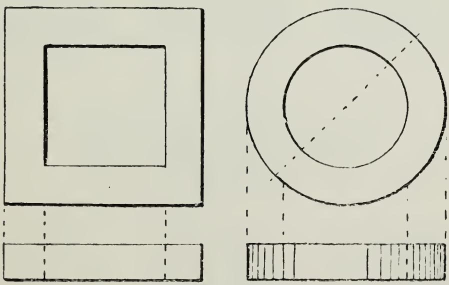


Fig. 4

Compasses.—A set of 4 in. or 4½ in. compasses with round or needle points, lengthening bar, and

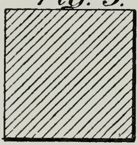
with pen, pencil, and divider points, should be procured, and it will be found convenient to have a spare pair of dividers, if possible, with screw adjustment known as "hair dividers."

Drawing Pen.—If it is intended to finish the drawings in ink, a drawing pen with hinged nib will be required; this pen should always be put away clean and dry, and the filling should be accomplished with a small brush—a small camel hair will suffice. On no account should a drawing pen be dipped into the ink; the habit is likely to lead to smeared lines and dirty work.

Spring Bows.—These will be found necessary for the construction of small circles, but this is only likely to occur in the advanced portions of the work.

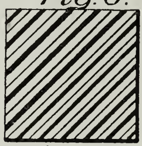
Sectioning.—Figs. 5 to 11 illustrate the conventional methods of hatching or sectioning the surface

Fig. 5.



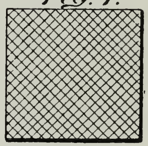
Cast Iron.

Fig. 6.



Wrot Iron.

Fig. 7.

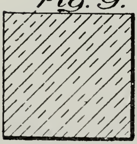


Lead

Fig. 8.

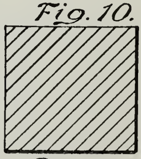
Wood.

Fig. 9.



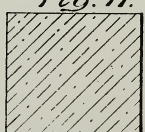
Stone

Fig. 10.



Brick.

Fig. 11.



Brass.

of material cut through. It is not advisable to grain surfaces other than cross sections. In coloured drawings the sections are shown of a darker tint, and, as a rule, the smaller the section the darker should the tint be made.

Dimensions to Working Drawings.—These should be placed upon the work as shown at Fig. 1, and great care should be taken to make the arrow points touch the lines from which the dimensions are taken, and to carefully mark the correct sizes. The above is rendered the more important from the fact that it is usual to insert in specifications the following clause: "Where any discrepancy exists between a scale drawing and a figured dimension, the latter is to be taken to be correct." Inches should be denoted by a double dash in the top right-hand corner (″), feet by a single dash (′). If no odd inches exist it should be indicated by placing a cipher in position, as 3′ 0″.

Datum Lines.—In commencing a drawing it is advisable to start upon a line which passes in a right direction across the paper, and to build up the work from it. This is termed a datum line, and is usually taken at "ground line," "floor line, "sill line," etc.

Lettering.—A good drawing is often spoilt by "writing up" or lettering badly. Upright or inclined block capitals may be used for headings, whilst small italics may be used for remarks. The following are examples of lettering that may be used:

A B C D E F

A B C D E F

a b c d e f

1 2 3 4 5 6 7 8 9 0

The student should avoid all unnecessary ornamentation, and bear in mind that although good lettering is essential, it is the drawing that should be the prominent feature.

Pencil Work.—When a drawing is to be finished in pencil, care should be exercised to avoid all superfluous lines, as in erasing the same, lines that should remain are often obliterated. Careful attention at the earlier stages would enable the student to avoid such errors.

Inking In.—Acid ink should not be used with drawing instruments or they will be liable to corrosion ; Indian ink in bottle will suffice where no colour is to be used. In order to insure good work with coloured drawings, the ink should be rubbed from the cake or stick.

Colouring.—The following is a list of conventional colours used for the representation of various materials:

Material.	Colour.
Fir (in the rough), -	Raw Sienna.
„ (wrought), - -	Burnt Sienna.
Oak, - - -	Sepia.
Mahogany, - -	Lake and Sepia.
Wrought Iron, - -	Prussian Blue.
Cast Iron, - -	Payne's Grey or Neutral Tint.
Brass, - - -	Gamboge.
Lead or Zinc, - -	Indigo.
Glass in section, -	Hooker's Green.
„ interior, - -	Cobalt.
„ exterior, - -	Indigo.
Earth, - - -	Sepia.
Brickwork (in section),	Lake.
„ (in elevation),	Indian or Venetian Red.
Slates, - - -	Neutral Tint.

In colouring, the paper should be glued at its margin to the extent of $\frac{1}{2}$ in. and made fast to the board, first damping to secure the paper being thoroughly stretched. Sufficient colour should be taken up by the brush to complete a wash, and starting from the top the colour should be worked from right to left, and *vice versâ* until the lower lines are reached, always sloping the board towards the draughtsman, in order to secure a perfect flow of the colour.

Small washes require to be made darker than the larger, and no second colour should be applied until the first has thoroughly dried. When the colour has become perfectly dry, and the drawing completed, a sharp pocket knife should be passed round the paper inside the glued margin and the paper lifted. The superfluous paper left upon the board may then be removed by a sponge and warm water.

CHAPTER II.

GEOMETRY AND PROJECTION.

Fig. 12. To bisect the angle between two straight lines. Let ABC be the given angle. With B as centre, and any radius, describe an arc cutting AB and BC in points D and E respectively. With points D and E as centres, and with any radius, describe arcs

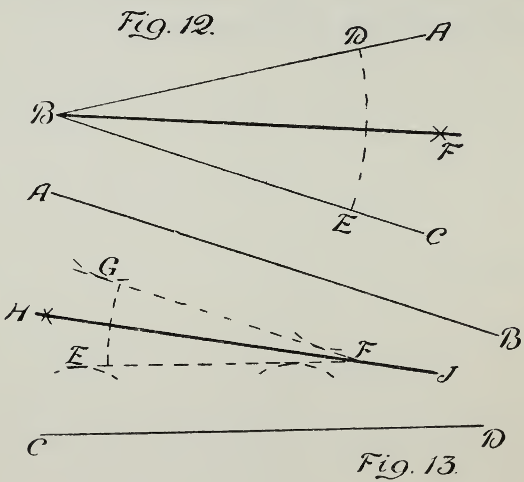


Fig. 12.

Fig. 13.

cutting each other in point F. Join BF. BF bisects the angle ABC.

Fig. 13. To bisect the angle between two converging lines when the point of intersection is inaccessible. Let AB and DC be the converging straight lines. Draw two lines GF and EF parallel to and at a convenient distance from AB and CD respectively, to intersect in point F. Bisect the angle GFE by the preceding problem. HF bisects the angle between the converging lines AB and DC.

Fig. 14. Through a given point to draw a straight line which shall converge to the same point as two convergent straight lines would if produced.

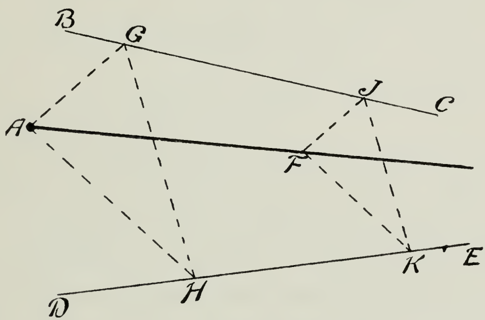


Fig. 14.

Let BC and DE be the convergent straight lines, and A the given point.

With A as apex, construct any triangle with base terminating on lines BC and DE in points G and H respectively. Take any point, J in BC—preferably remote from G—and draw JK parallel to GH, and terminating on DE in point K. Draw JF and KF parallel to GA and HA respectively, and join A and F. The line AF converges towards the same point as BC and DE.

Fig 15. To draw a circle which shall pass through any three given points, not in the same straight line.

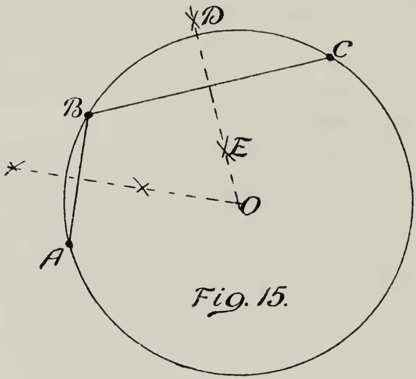


Fig. 15.

Let *A*, *B* and *C* be the three given points. Join *AB* and *BC*. With points *B* and *C* as centres, and with any radius, draw arcs cutting in points *D* and *E*. Join *DE* and produce: *DE* then bisects *BC* at right angles, it therefore contains the centre. Repeat the process with points *B* and *A*, allowing the bisecting line to intersect *DE* produced in *O*. *O* is then the centre of the circle which passes through the three given points.

Fig. 16. To draw an arc of a circle to pass through any three given points not in the same straight line, the centre not being accessible (Builders' Method).

Let *A*, *C* and *B* be the three given points.

Join points *AC* and *CB*, and construct a template of strips of wood, as shown in the figure. The angle at *C* is now fixed. By allowing the laths *AC* and *CB* to slide around in contact with points *A* and *C*, and by

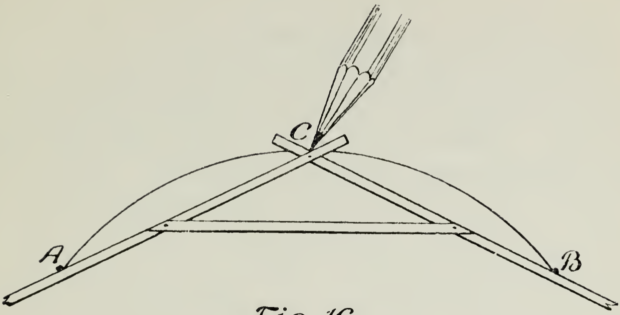


Fig. 16

applying a pencil to the point C, the arc ACB is traced.[1]

Fig. 17. To inscribe a regular polygon, of any number of sides, in a given circle.

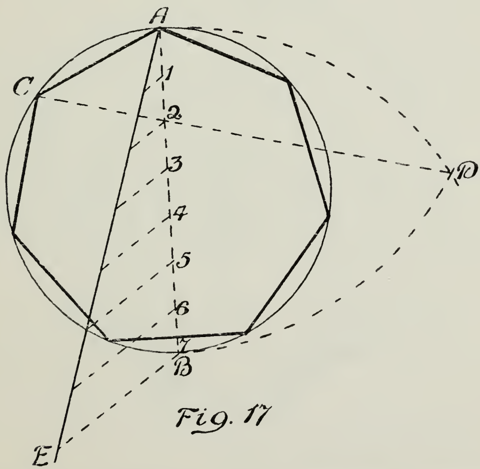


Fig. 17

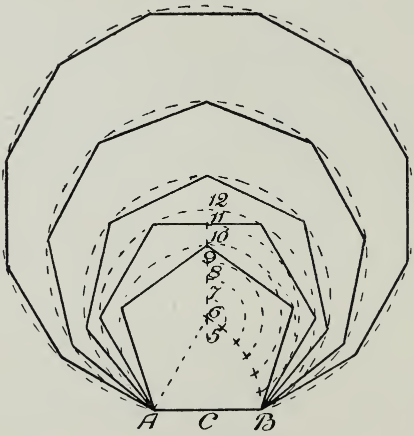
[1] This problem is based on a very important principle of the circle, viz., the angles in the same segment of a circle are equal to one another.—Prop. xxi. Book III. *Euclid.* The angle contained between the laths in the case being fixed, it necessarily follows that the point of the pencil placed in the angle at C traces the part of a circle.

Let *ABC* be the given circle.

Draw the diagonal *AB*, and divide it into such a number of equal parts as the polygon has sides, and number. With *A* and *B* as centres, and with radius *AB*, describe arcs cutting at point *D*. Join *D* with point 2 upon the diagonal and produce to cut the circle at point *C*. Join *A* with *C*; *AC* will then be one side of the polygon. With *AC* in the compasses, proceed to mark off equal distances on the circle, and by joining the points complete the figure.

Fig. 18. Upon a given line to construct a regular polygon of any number of sides (up to twelve).

Fig. 18.



Let *AB* be the given line.

Bisect *AB* in *C* and erect a perpendicular from the centre. With *A* as centre, and *AB* as radius, describe an arc intersecting perpendicular in 6. Divide the arc 6*B* into six equal parts. With point 6 as centre, and with each of the divisions taken consecutively from 6,

describe arcs cutting perpendicular in points 7, 8, 9, 10, 11, 12 respectively. These points are the centres of circumscribing circles of polygons, having sides corresponding to the number of their centres.

Fig. 19. To draw a tangent to a given circle from a point outside the same.

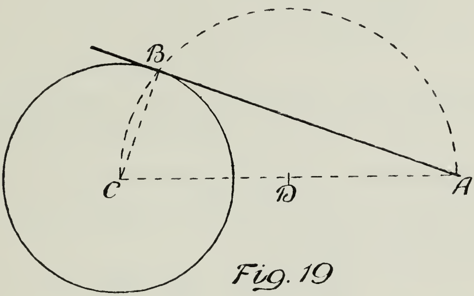


Fig. 19

Let the given circle be about the point *C*, and the given point *A*.

Join *CA* and bisect in point *D*.

With *D* as centre, and *DC* or *DA* as radius, describe a semicircle cutting the circle about *C* in point *B*. Join *AB* and produce. *AB* is a tangent to the circle about *C*.

N.B.—A tangent to a circle is a line which touches it in a point, and in such a way that it is at right angles to the radius at that point.

Fig. 20. To find the geometric mean between two lines.

Let *A* and *B* be the given lines.

Draw the line *CD* equal to *A* and produce to *E*, making *DE* equal to *B*. Upon *CE* construct a semicircle. At *D* erect a perpendicular cutting the semicircle in point *F*.

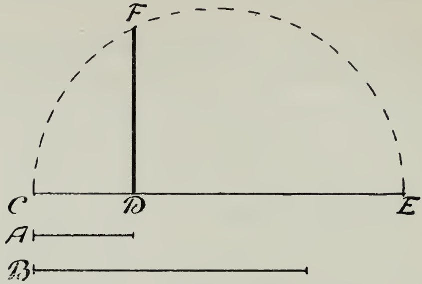


Fig. 20

DF is then the geometric mean between *A* and *B*. In other words, *CD* is to *DF* as *DF* is to *DE*.

The importance of this problem will be seen from the fact that the square on *DF* is equal to the rectangle contained by *CD* and *DE*.

$$CD : DF :: DF : DE$$
$$\therefore \quad DF \times DF = CD \times DE$$
$$DF^2 = CD \times DE.$$

N.B.—The area of any rectangular figure is equal to the product of its two adjacent sides.

Fig. 21. To find a square equal in area to a given triangle.

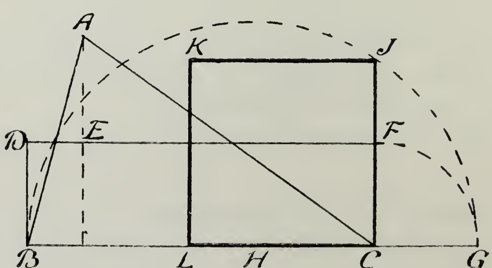


Fig. 21.

Let *ABC* be the given triangle.

N.B.—The area of a triangle is equal to the area of a rectangle upon the same base, and having half its height.

From *A* drop a perpendicular to the base, and bisect it in point *E*. Draw *DF* through *E* and complete the rectangle *DFCB*. Obtain the mean proportional *JC* between the sides *BC* and *CF*, as in previous problem.

The square *LCJK*, being constructed on *JC*, is equal in area to the triangle *ABC*.

Fig. 22. To reduce an irregular quadrilateral figure to a square of equal area.

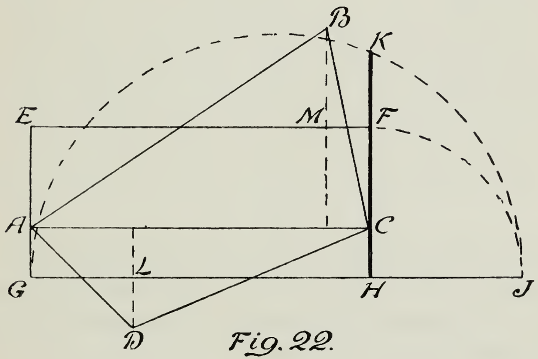


Fig. 22.

Let *ABCD* be the given irregular quadrilateral figure.

Draw the diagonal *AC*; this reduces the figure to two triangles. The two triangles should now be reduced to two rectangles of the same area, having their sides *AC* common to one another. The rectangle *FEGH* may now, by preceding problem, be reduced to a square of equal area.

The square on the line *HK* is equal in area to the irregular quadrilateral figure *ABCD*.

Fig. 23. To reduce a circle to a parallelogram of equal area.

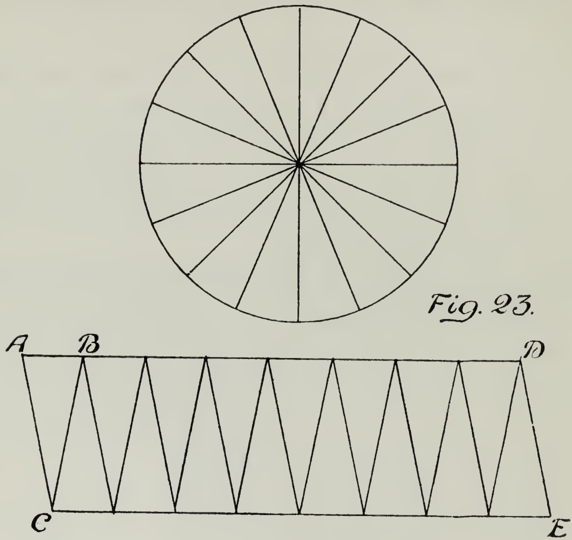


Fig. 23.

N.B.—This method is but an approximate one, and depends for its accuracy upon the number of sectors taken; the greater the number of sectors adopted the more correct will be the result.

Divide the circle into sectors (see note above). These sectors may, for the purposes of approximation, be considered as triangles, and, being placed as *ADCE*, with their apices reversed and their sides coincident, they then form the required parallelogram.

Fig. 24. To construct an ellipse the major and minor axes being given (string method).

N.B.—This method—a strictly mathematical one—is based upon the fact that, in the ellipse, the sum of the focal distances is constant and equal to the major

axis. Set out *AB* and *CD*—the major and minor axes —perpendicular to, and intersecting each other at *E*, the common points of bisection. With *C* as centre, and the semi-major axis as radius, mark off points F_1 and F_2—the focal points. Insert pins at F_1 and

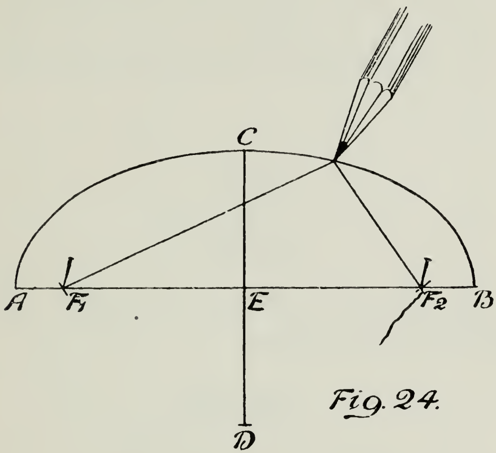


Fig. 24.

F_2, and fix one end of a thread at F_1. Allow the thread to pass to point *A* and back to point F_2, giving it one or two turns to secure it. Apply the point of the pencil to point *A*, and, keeping the thread uniformly stretched, proceed to draw the curve.

In this example, only one half of the curve has been traced.

Fig. 25. In a given rectangle to draw an ellipse.

Let *ABCD* be the given rectangle. Bisect the rectangle in two directions by lines parallel to its sides. Divide half the side *BF* and the semi-major axis into any number of equal parts, and from points *G* and *E* draw lines 1, 2, 3, etc. Through the points of inter-

section draw a fair curve. If this operation be repeated in each quarter of the rectangle, an ellipse will be traced.

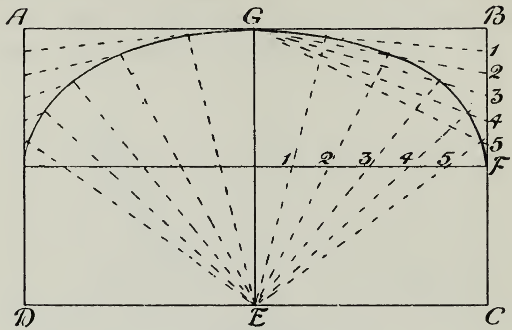
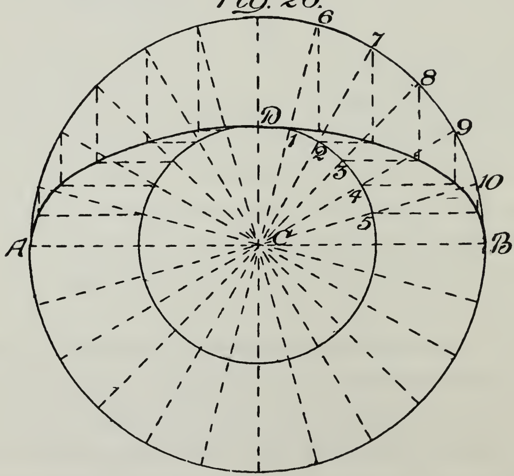


Fig. 25

Fig. 26. To draw an ellipse by points, the major and minor axes being given.

Fig. 26.



Draw the axes at right angles to each other, and

with their centres coincident. With these lines as diagonals draw two circles. Draw any number of diagonals, and through the points where they intersect the circles, draw lines parallel to the major and minor axes. Through the points of intersection draw a fair curve; this will be the required ellipse.

Fig. 27. To draw a tangent to an ellipse, also a normal to the curve at the same point.

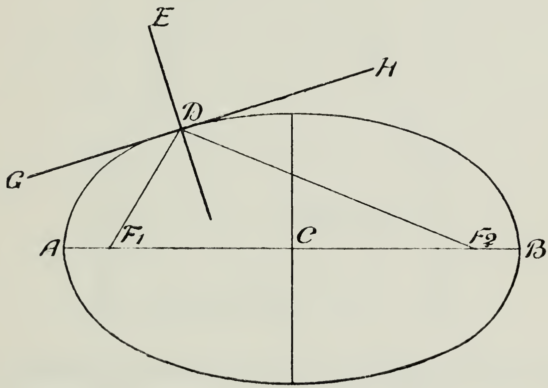


Fig. 27.

Find the focal points as in the figure, and through point *D* draw the focal lines; bisect the angle between them, by the line *ED* produced; *ED* will then be a normal to the elliptic curve at the point *D*. Through the point *D*, and at right angles to it, draw the line *GH*. *GH* will be the required tangent.

Fig. 28. To draw the curve of a parabola, the base and altitude being given.

Let *AB* be the base and *CD* the altitude. Complete the rectangle *ABEF*. Divide *BC* and *BE* into any number of equal parts. Through points 1, 2, 3,

4, 5 on *BC* erect lines parallel to *CD*, and through similar points on *BE* draw lines radiating to the point *D*. The parabola will be represented by a fair curve traced through the points of intersection.

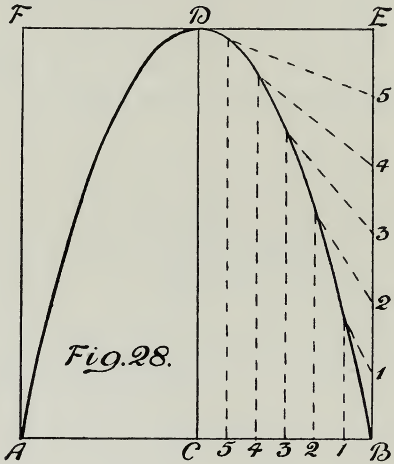


Fig. 28.

N.B.—The parabola is the curve represented in the outline of a section through a cone, taken parallel to its slant side.

Fig. 29. To draw the hyperbolic curve from the cone.

N.B.—The hyperbola is the curve represented in the outline of a section of a cone by a plane which is of steeper inclination than the slant side, and which does not contain the axis.

The curve is here drawn directly from the cone, the elevation and half-plan of which are given.

Draw in elevation and plan a series of circles passing around the cone and nearing each other as they approach the apex. These circles will, in plan,

cut the line EF—the H.T. of the section plane—in points, the elevations of which will be found upon

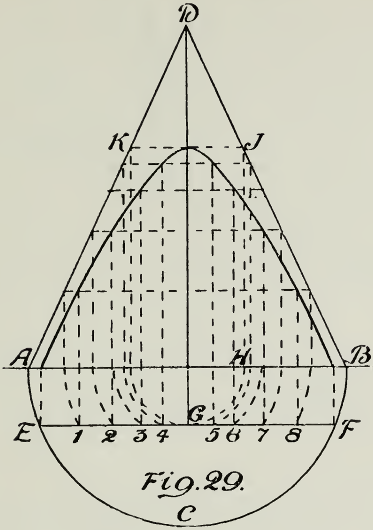


Fig. 29.

their respective circles, and through them a fair curve —the hyperbola—may be drawn.

Fig. 30. To draw the hyperbolic curve by mechanical means, the abscissa CA and focal points F_1 and F_2 being given (string method).

N.B.—This method is based upon a very important principle of the hyperbola, viz., that the curve is such that the difference in the distances of any point in the curve from points F_1 and F_2 (the focal points) is constant.

Take a lath of convenient length, as F_2E, pivot it at F_2, and fasten a convenient length of thread to the end E. Pass the thread to point C and back to F_1, making it fast. By applying a pencil to point C, and

keeping a uniform tension upon the thread, the required curve may be traced.

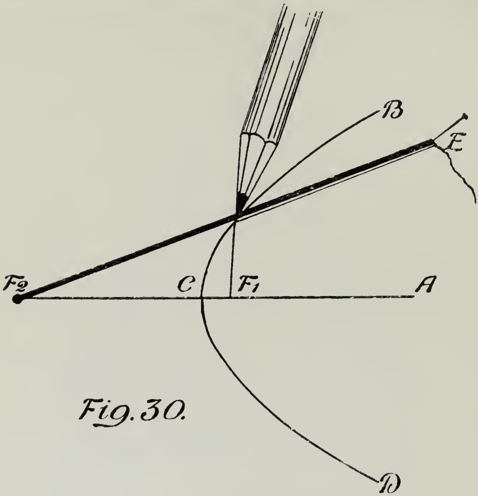


Fig. 30.

Fig. 31. To construct the parabolic curve by mechanical means; the directrix *CD* and focal point F_1 being given.

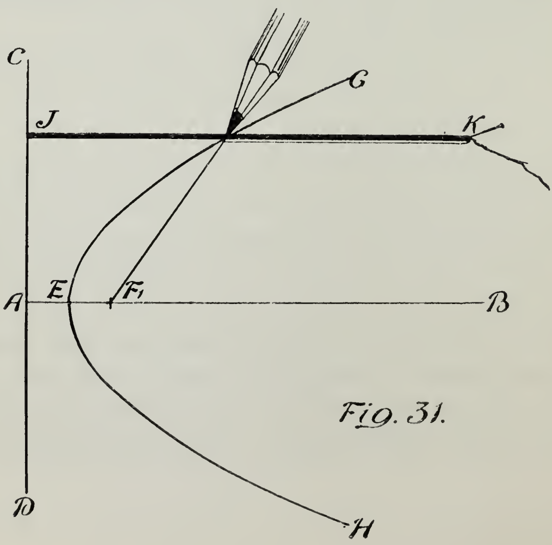


Fig. 31.

N.B.—One very important principle of the parabola is, that any point in the curve is at the same distance from both the directrix and focal point.

Through F_1 draw AB perpendicular to CD, terminating on it in point A. Bisect F_1A in E; E will then be a point on the curve. Take a lath of convenient length, as JK, and at K attach the thread. Place the fiducial edge of the lath on AB and pass the thread to point E and back to the pin at F_1, giving it a turn or two for the purpose of securing it. By sliding the end J along DC, always keeping JK at right angles to it, and, by keeping the thread stretched, the point of the pencil will trace the parabola HEG.

Fig. 32. Given two points on the elliptic curve, the direction of the major axis, and one of the focal points, to draw the curve.

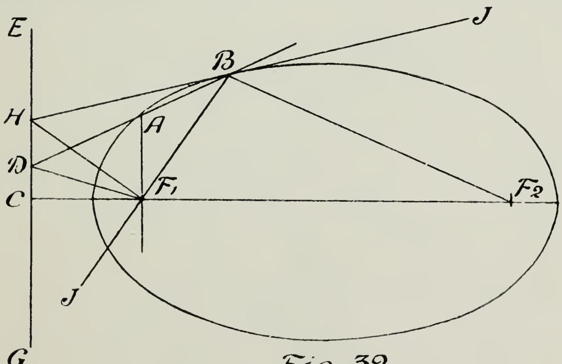


Fig. 32

Let A and B be the two points through which the curve has to pass, CF_1 the direction of the major axis, and F_1 the focal point.

Join AF_1 and BF_1 and produce to J. Bisect the exterior angle AF_1J. The chord line BA will, if pro-

duced, intersect the bisecting line of the exterior angle in the directrix of the ellipse; this point is here marked D. Through D draw GE at right angles to CF_1. Select one of the points—here point B—and from it draw BF_1—a focal line. Draw F_1H at right angles to BF_1, meeting the directrix in the point H. Through H draw the tangent HBJ, and construct the angle JBF_2 equal to HBF_1 and intersecting the major axis in F_2. The focal points being obtained, and at least one point upon the curve, the ellipse can be completed by a previous problem.

ORTHOGRAPHIC PROJECTION.

This is the method of projecting points, lines, surfaces, and solids upon planes not containing them. It is usual to use at least two planes, called the "planes

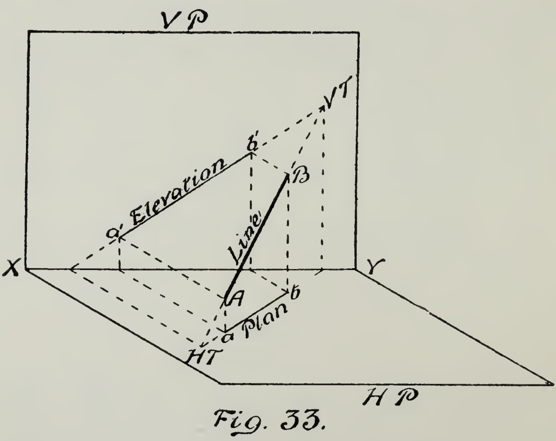


Fig. 33.

of projection," "co-ordinate planes," and sometimes vertical and horizontal planes, because they are considered to occupy these positions. Fig. 33 is a sketch

of two such planes. For the purposes of this representation the planes are bounded by lines, but in reality they are unlimited, and the only character by which they may be represented in orthographic projection is by the ground line or XY. For the convenience of drawing, these planes are rotated into one plane—the plane of the paper. Perpendiculars let fall upon the planes from points in space are termed "projectors," and their intersections upon the planes, "projections." Drawings made upon the V.P. are known as "elevations," those upon the H.P. as "plans." In order to distinguish between plans and elevations, letters denoting the latter have a small dash placed above them, as a'.

Fig. 34. To find the true length, traces, and inclinations ϕ and θ of a line given in plan and elevation.

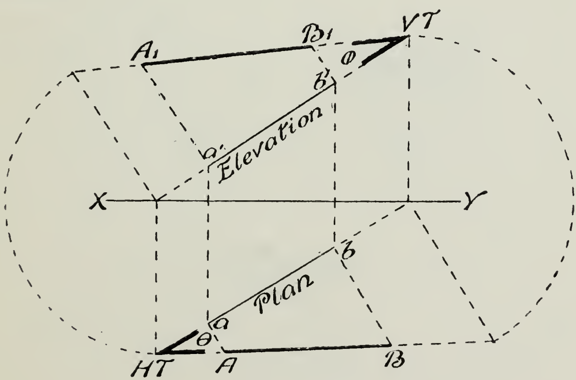


Fig 34.

Let $a'b'$ represent the elevation, and ab the plan.

N.B.—The angle of inclination to the vertical plane is denoted by the Greek letter ϕ (phi), whilst that

to the horizontal plane is marked by the letter θ (theta).

From the preceding figure it will be found that the line forms part of the hypotenuse of two right-angled triangles, and by hinging them about the elevation and plan they may be turned back into the V.P., or down into the H.P. By this means its true length may be obtained; it also follows that if the angle of inclination of a line to a plane is measured by the angle contained between the line itself and its projection upon that plane, the angle contained between A_1B_1 and $a'b'$ (Fig. 34) represents the angle to the V.P. (ϕ), whilst the angle contained between BA and ab represents the angle to the H.P. (θ).

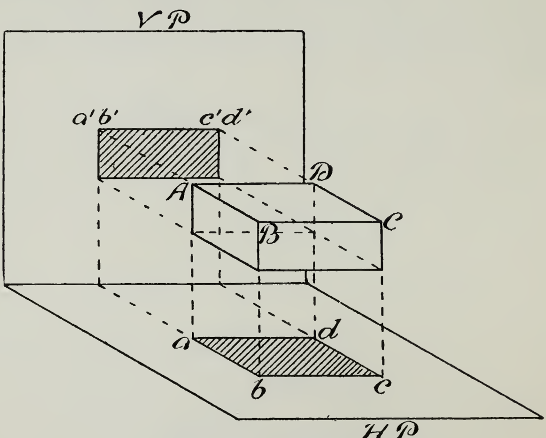


Fig. 35

Fig. 35 is a sketch representation of a rectangular slab standing out in space, its plan and elevation being given in Fig. 36. The top surface only of this solid is lettered.

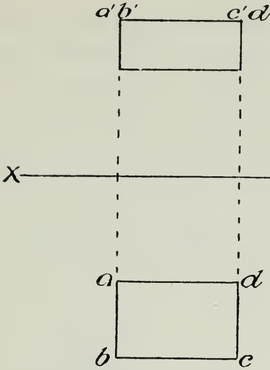


Fig. 36

Fig. 37. To develop the surface of a cone, the plan and elevation of which is given.

Let $a'b'c'$ be the elevation, and the circle bc its plan.

Through a — the plan of the apex — draw a series of diagonals cutting the circumference in equal parts. These lines in plan divide the surface into a series of sectors, the true length of the sides of which are represented in the elevation by $a'c'$ or $a'b'$. With a' as centre, and $a'c'$ as radius, describe an arc of sufficient

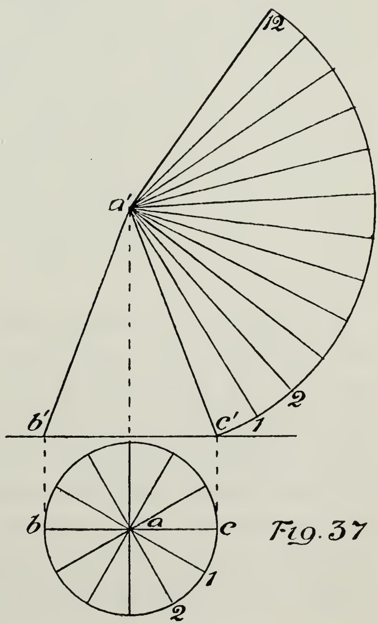


Fig. 37

length to pass around the base of the cone; this may be determined by taking the true distances *c*1 and 12, etc., from the plan and marking off a like number upon the larger arc *c*′12. The sector of the larger circle, contained between the radii *a*′*c*′ and *a*′12, represents the development of the surface of the cone.

Fig. 38. To find the plan and true form of section of a given right hexagonal pyramid cut by the plane *SN*.

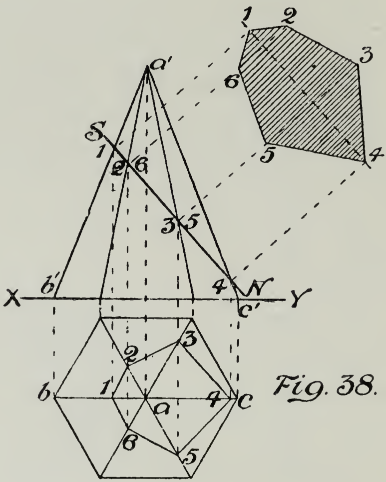


Fig. 38.

The plane *SN* passes perpendicular to the vertical, and intersects the slant edges in points 1′, 2′, 3′, 4′, and 5′. By projecting them down to their respective plans, the outline in plan may be obtained. To obtain its true form of section, it will be necessary to see that the outline is symmetrical about its axis *bc* or 1, 4, and that the distances 2, 6, and 3, 5, being parallel to the H.P., their plans represent their true length. Set off projectors from points 1, 2, 3, 4, 5,

and 6, at right angles to *SN*, and parallel to it draw the axis of the section 1, 4, at such a distance as to be clear of the elevation. Set off distances 6–2 and 3–5. Join the points 1–2, 2–3, etc., and the true form of section is complete.

ISOMETRIC PROJECTION.

The representation of an object in isometric projection enables the student to convey a true idea of the shape and sizes of such object by means of one drawing. The method has, for simple objects, a distinct advantage over the plan and elevation method, which requires at least two projections; whilst at the same time a regularly graduated rule may be employed for the purposes of taking off dimensions. Fig. 39 represents a small block in isometric

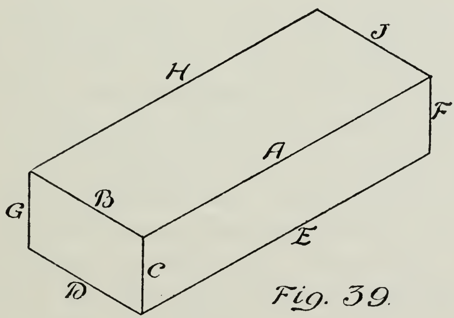


Fig. 39.

projection, its length, breadth, and thickness being represented by the three axial lines *A*, *B*, and *C* respectively.

There are two kinds of isometric projection, the first and simplest of which is called "Conventional

Isometric Projection," from the fact of its being adapted for use with the ordinary rule. The second

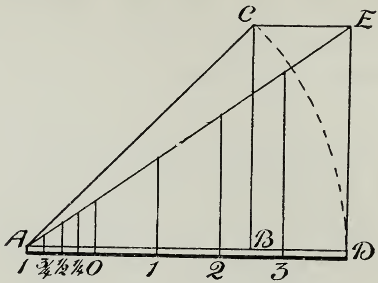


Fig. 40.

requires an "isometric scale," illustrated in Fig. 40, and is known as "Pure Isometric Projection."

CONVENTIONAL ISOMETRIC PROJECTION.

If the student will take a piece of wood similar to that illustrated in Fig. 39, he will see that the surfaces are bounded by straight lines. These lines are the characters by which the surfaces of the block are represented; he will further notice, upon placing the block upon the bench or table before him, that the lines bounding the surfaces are either vertical or horizontal. In order to represent these lines in isometric projection it will be necessary to remember two rules (applicable to either method). They are as follows: (1) Vertical lines are drawn vertical; (2) Horizontal lines are drawn at 30° to the horizontal, either to the right or left.

First draw the small vertical line marked *C* (Fig. 39), of a length equal to the thickness of the

block, and from its extremities draw two lines on either side, each at 30° to an imaginary horizontal line. Cut off the lines to the left equal in length to the width of the block, and those to the right equal to the length of the block. Now join the extremities of the lines at the right and left by vertical lines. These should be of a length equal to the vertical line at *C*. Now by drawing lines from the tops of the vertical lines last drawn, and in the direction indicated in the sketch, taking care that the lines *EAH* and *DBJ* are respectively parallel to one another, the drawing will be completed. What has been said with regard to the rectangular block may be applied to more complicated work.

On examining Fig. 41 he will now see that the moulding shown in that figure is formed out of a

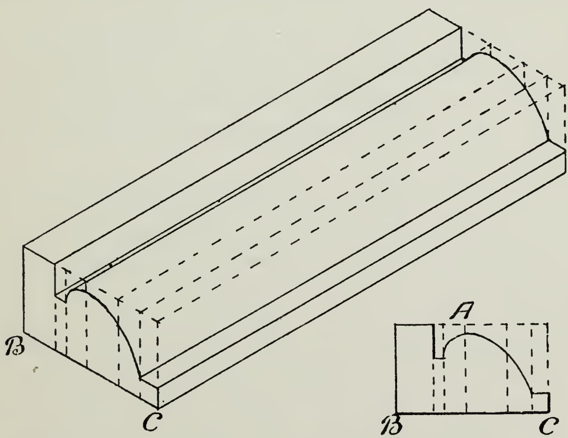


Fig. 41.

similar piece of material to that of Fig. 39, but having a partially curved outline it appears to

present some difficulty. The curved surface of the mould may be said to be traced by a straight line moving between the outline of the section of the moulding at its ends, so that all that remains to be done is to trace upon the ends of the block this outline in isometric projection. This may be done by constructing an auxiliary elevation of the end view as at Fig. 41, supplying ordinates to the curve, running up perpendicular to the line *BC*. But *BC* is already drawn in the isometric view in its real length, so that the position of points upon this line may now be conveyed to that line, and the perpendiculars corresponding in length to those in the auxiliary elevation may now be drawn, remembering that perpendicular lines should be drawn vertically and not perpendicular to *BC*. A fair curve around the topmost extremities of these lines should now be drawn and the isometric projection of the section of the moulding is complete. It now remains to repeat the operation at the other end and draw the necessary lines parallel to the long edges to complete the figure.

In order to show how plain surfaces, other than those mutually perpendicular, may be represented, the corner joint of the Oxford frame has been selected (Fig. 42). The student will readily see by the aid of the dotted lines how the points are obtained in that figure, and it should be carefully noted that it is not the angle at which the "stop" is cut, but the distances along the length and across the thickness and breadth of the material that guide him in placing that stop in position. Other exercises may be found in the chapter bearing upon joints, which

the student is recommended to reproduce, not only for the purpose of committing to memory the form of construction, but to acquire the ability to rapidly portray the form upon paper.

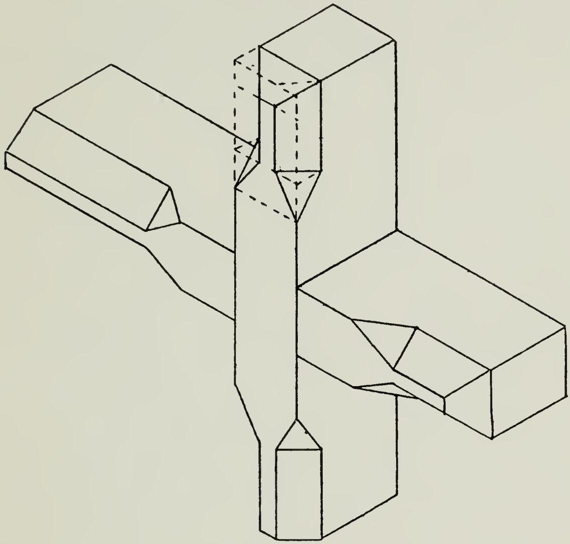


Fig. 42.

Pure Isometric Projection.—With drawings plotted by this method, it will be necessary to use an isometric scale, the rules with respect to horizontal and vertical lines remaining as in the case of conventional isometric projection. This scale will not be so difficult as at first sight it appears, if the student will follow the reasoning here laid down.

In drawing a circle in isometric projection, it is usual to first plot the square which is to contain it, and then to trace the circle by means of ordinates as in Fig. 41. On examining the representation of the

circle when complete, it will be found that neither the major nor the minor axis truthfully represents its diameter. Apart from this, the horizontal axis of the square will be much extended. To counteract this error, the isometric scale shown in Fig. 40 has been suggested; it is brought about in the following manner.

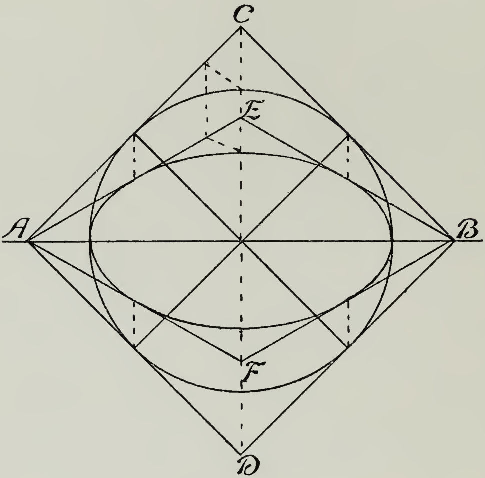


Fig. 43.

Fig. 43 represents a square *ADBC* plotted in an ordinary manner and with one diagonal *AB* horizontal. The square may now be imagined to rotate about *AB* until its sides appear at angles of 30° with the horizontal axis; in this position the square may be said to be represented in "pure isometric projection" by the parallelogram *AFBE*—the length of the horizontal diameter or axis being kept constant—the sides of which now bear the ratio to those of the square as $\sqrt{2}$ is to $\sqrt{3}$. In Fig. 43 the circle has also been

represented in pure isometric projection by an ellipse the major axis of which represents truthfully the diameter of the circle. The author has adopted this method of explaining the construction of the isometric scale in preference to the one more generally made use of, and which is next described.

It has been explained that the isometric scale bears a ratio to that of the natural scale as $\sqrt{2}$ is to $\sqrt{3}$. In Fig. 40 AB has been laid down of any length and BC erected at B, equal and perpendicular to AB. Join AC and with this line as radius and A as centre, describe the arc CD intersecting AB produced in D. At D erect DE parallel and equal to BC, and join AE. If the line AB be taken as unity, then AC represents the square root of two ($\sqrt{2}$) and AE the square root of three ($\sqrt{3}$). The natural scale may now be constructed on AE, and by dropping perpendiculars upon AD the isometric scale is constructed.

CHAPTER III.

JOINTS USED IN CARPENTRY AND JOINERY.

THE work of the carpenter and joiner may be summed up as the building up of a series of timbers to the form or plan of a design laid down, and such is the nature of the material with which he is called upon to work that it requires the greatest care, in the formation of the joints, in order to maintain, as far as possible, the strength of the material employed, and, at the same time, to allow for its expansion and contraction without warping or twisting. In all cases those timbers upon which the strength of a piece of work may depend should not have their sectional area destroyed any more than is absolutely necessary. More especially is this the case where the work is to be subjected to great stress, as in partitions, bridge or roof structures. The timber used in construction is known by a variety of names according to its size or form: the following is an explanation of some of the terms employed.

Log.—The trunk of a tree previous to being squared.

Balk.—The log roughly squared.

Half-timbers.—The balk split or sawn through its centre, along its length; in half-timbers the heart is

usually exposed. The term "flitch" is also applied to timbers sawn longitudinally through the heart. Oak timbers split in this manner are known as wainscotted.

Spar.—Sawn timbers, such as are suitable for roofing work.

Plank.—Sawn timbers, of any length, ranging upwards from 11 in. wide and from 2 in. to 4 in. thick.

Deal.—Sawn timbers ranging from 9 in. by 2 in. to 11 in. by 4 in.

Board.—Any timbers between 7 in. and 11 in wide and less than 2 in. thick.

Quartering.—Sawn timbers of any length and ranging from 3 in. by 2 in. to 4 in. by 3 in.

Batten.—This term is applied to any small timbers, not coming under the head of "quartering," and which is less than 7 in. wide.

Scantling.—This is a term often applied to a collection of a variety of small timbers, but is more properly applied to the tabulated or specified sizes of the several parts of a piece of framing.

Stuff.—This is the term usually applied to the material during the process of working.

Sawn timbers are said to be "in the rough." The members of roofing trusses or partitions are ofttimes left as from the saw, and as such are specified as being "in the rough." When woodwork has one surface only planed, it is said to be "single wrought"; this may be illustrated in the case of dado framing and the backs and elbows of window framing; but when, as in the case of doors, sashes etc., both the surfaces are planed, the material is known as "double wrought."

It was at one time the custom to allow the diminution of $\frac{1}{8}$ in. for each wrought surface, so that a door specified as 2 in. was supplied at a finished thickness of $1\frac{3}{4}$ in. This method, although a recognized one, caused a great deal of dissatisfaction; and to overcome the difficulty, work is now specified as of the required dimension with the words "finished size" inserted.

Planing is the process of taking off the rough fibre left by the saw upon the surface of the stuff.

When the planed surface has been prepared truthfully and with a view to further manipulation, it is said to be "faced up" and, in order to distinguish it from sides not so faced up, it is pencil-marked at or near the face-edge. This latter surface or edge sometimes requires to be specially prepared and, when so prepared, is said to be "shot," the process of preparation being termed "shooting." This face-edge also receives a distinguishing mark—usually a cross—the arms of which should terminate upon the arris near the face-side. It is to this face-side or edge that the stock of the square or fence of the gauge should be applied in the process of gauging or squaring. The face-mark as applied to the surface of the work is illustrated in Figs. 45 and 46.

The following may be considered as a brief outline of the more useful of the joints which the carpenter and joiner may be called upon to make use of in the process of framing up material.

Lap or Halved Joint.—This is formed by the cutting away of one half from the thickness of each of two pieces at their extremities; it is illustrated at Fig. 44, and is used for the purpose of connecting the ends of material as in the case of two wall plates.

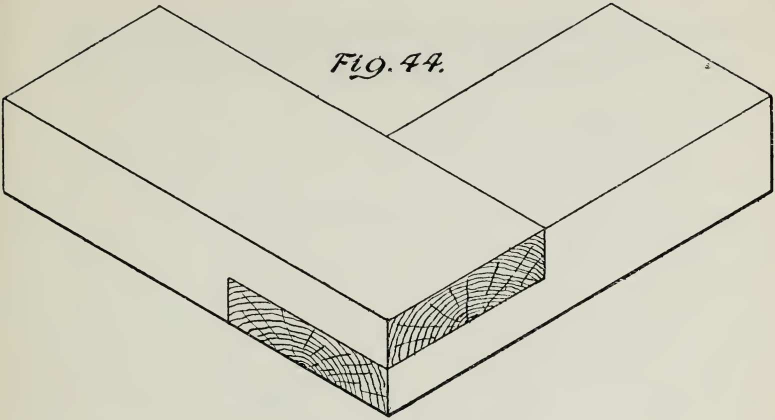


Fig. 44.

Mitred and Halved Angle Joint.—This joint, shown at Fig. 45, differs from the preceding one in that the

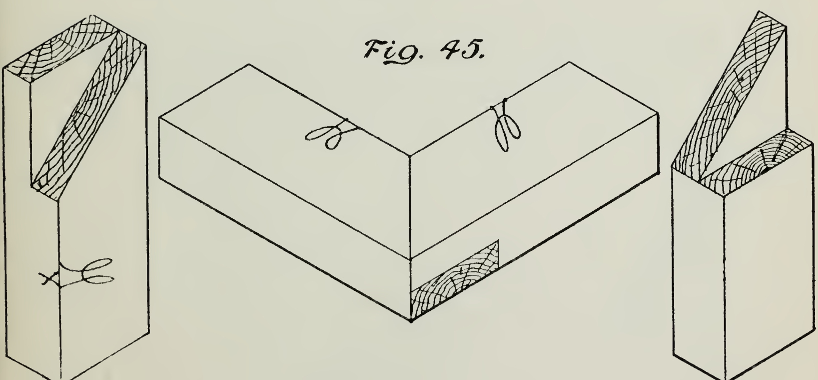


Fig. 45.

shoulders of the face-side are mitred: this is the usual form adopted when the face of the work receives a moulding.

Open Mortise and Tenon.—This joint, shown at Fig. 46, is formed by taking away the two outer thirds

from one piece and the middle third from the other, the shoulders passing in the same direction on both sides.

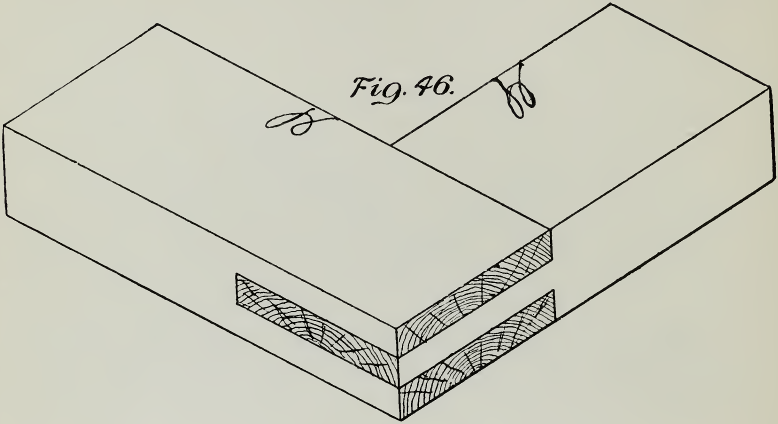


Fig. 46.

Mitred Joint.—This form of joint is required where the adjacent surfaces are moulded, as at Fig. 47.

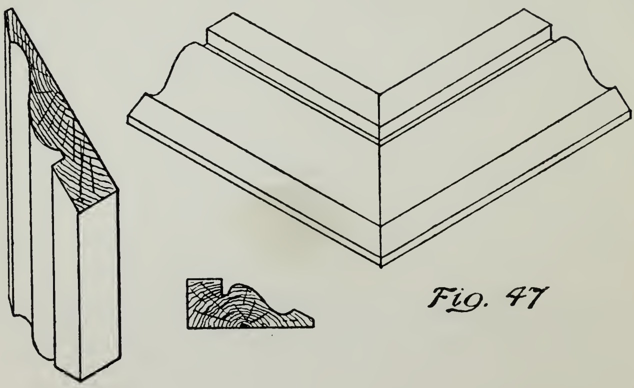


Fig. 47

Open Mortise and Tenon with Mitred Shoulders.—Fig. 48 shows a form of joint having the combined

advantages of those shown in Figs. 46 and 47. Its form will readily be seen from the figure.

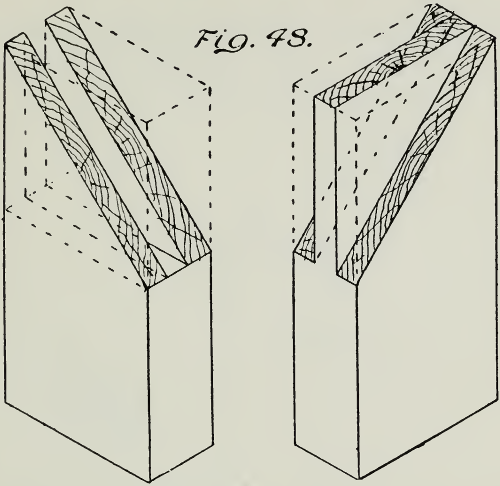


Fig. 48.

Notch Joint.—When a part of one piece has been cut away for the reception of another, as at Fig. 49, it is said to be notched. Ceiling joists have sometimes

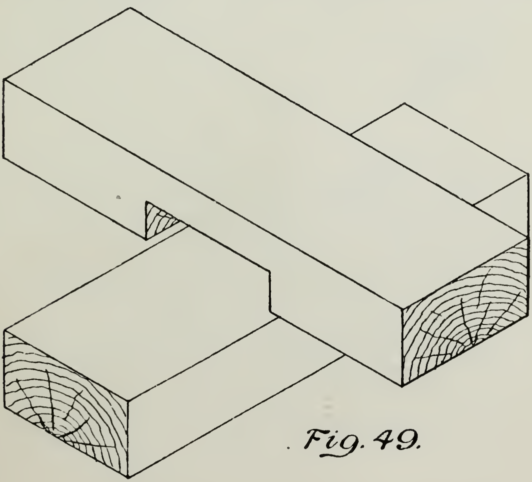


Fig. 49.

to be notched to binders; but when, as in Fig. 42, Chap. II., both pieces are cut away, it is said to be double-notched.

Dovetail Notch.—This is another form of the notched joint, the upper portion being cut in the form of a dovetail (see Fig. 50).

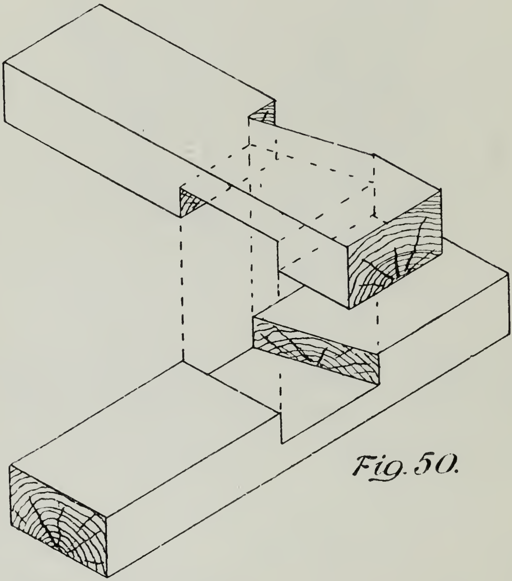


Fig. 50.

Tredgold's Notch.—Fig. 51 represents the form of notch recommended by Tredgold. Whatever may be said in favour of the joint, it is weak at the neck, and the labour involved in its construction makes it less adapted to more general use.

Dovetail Halved Joint.—This joint is made use of in the junction of the end of one piece of material with another, either at the end or towards the centre,

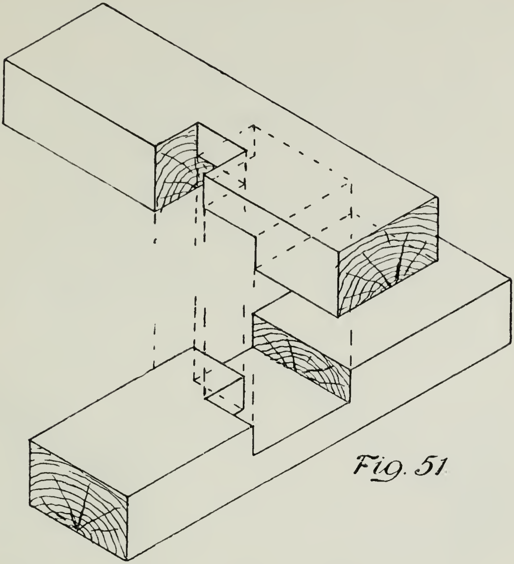


Fig. 51

as shown at Fig. 52. In the former case, only one side of the top piece is cut away, the remainder being known as a half dovetail.

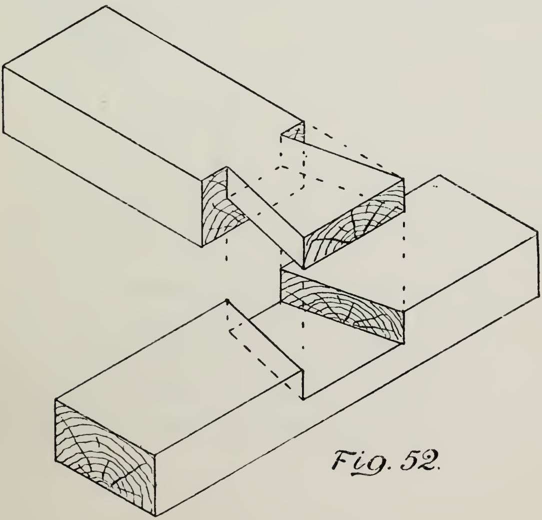


Fig. 52.

Cogged Joint.—Upon referring to Fig. 49 it will be seen that the ends of the notch fit down over the edges of the piece below. If these ends were cut closer and were allowed to rest in notches cut into the vertical edges of the other, such joint would be known as cogged. It is illustrated at Fig. 4, page 80.

Tongue and Groove Joint.—This is a joint which is very much used both in carpentry and joinery. As will be seen at Fig. 53, it is made by the formation

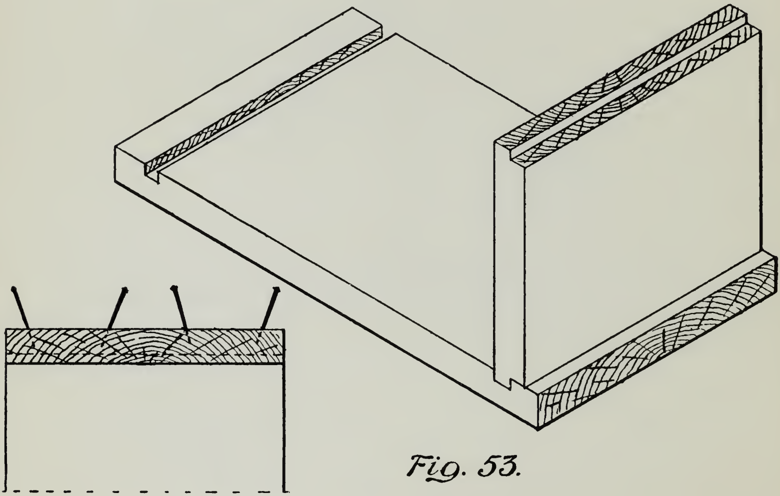


Fig. 53.

of a tongue upon one piece, whilst a groove is cut into the other, into which the tongue should tightly fit. It is further secured by glueing and sometimes nailing. In all cases of nailing it gives greater security if the nails are driven in an inclined direction, as shown at Fig. 53. Another form of this joint is made use of between floor boards, as shown at Fig. 2, page 71, the tongue being formed of either wood or iron, and as

it is termed when thus formed of separate material—loose.

Dovetail Tongue and Groove.—At Fig. 53*a* is shown another form of tongue and groove: in this

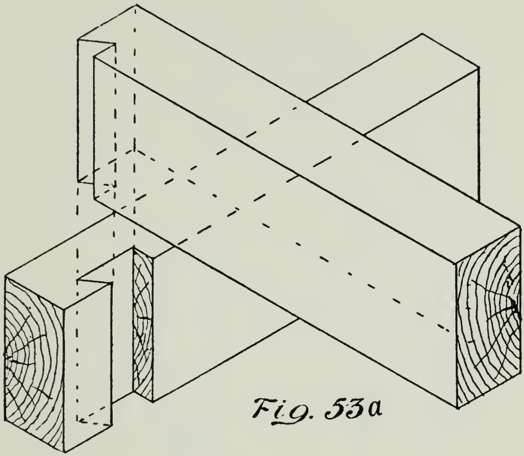


Fig. 53a

case the former is dovetailed, which gives it security without the use of nails.

Tusk Tenon.—This is a form of joint without the use of which few floors are made. It is used in connecting the trimmers with the trimming joists, and again at the ends of trimmed joists. It is composed of haunchion, tenon, tusk, and shoulder, and should be arranged as at Fig. 5, page 75. Tredgold recommends the following proportions. Taking the depth of the piece as D: the haunchion should be $\frac{5}{12}$ D, the tenon $\frac{1}{6}$ D, the tusk $\frac{1}{6}$ D, and the shoulder $\frac{1}{4}$ D. The depth at which the tusk and haunchion should penetrate the piece mortised is recommended to be $\frac{3}{24}$ D. By this arrangement the mortise is kept in the centre

of the depth of the timbers; this is important, as, being the "neutral line or axis," the fibres are of least importance at this part. The tenons at the ends of trimmers usually pass through the trimming joists and project beyond to an extent equal to the width of the tenon, and are mortised, as shown in the figure, for the insertion of a wedge or key, space being allowed at the back of the wedge for the purpose of closing the shoulders. In special cases, where trimmers meet the wooden girder so as to be in a direct line across it, the tenons should not pass through further than is necessary for the purpose of pinning.

Scribed Joint.—This is shown at Figs. 54 and 55, and may be described as the butting of one moulded

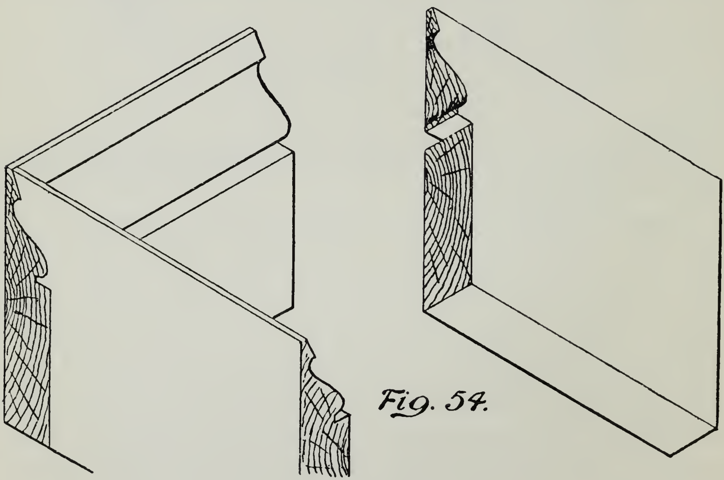


Fig. 54.

surface against another at an angle with it; for this purpose the end of one of the pieces has to be cut to the profile of the other. It has an advantage over the mitred joint insomuch as it allows the moulded surface

of the one in shrinking to slide over the surface of the other without gaping. In skirtings the internal angles

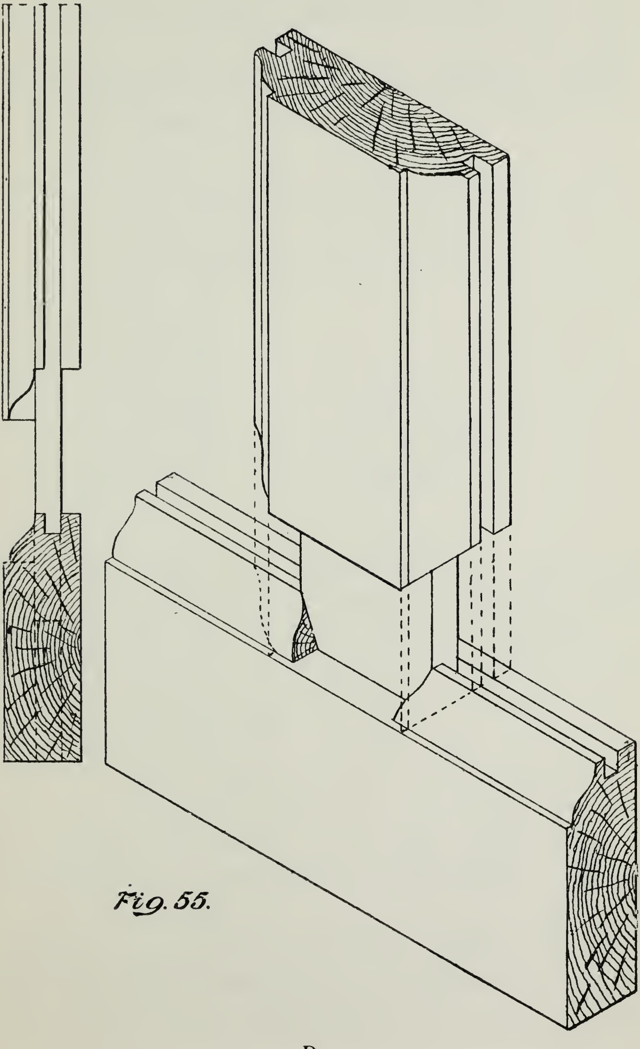


Fig. 55.

should be scribed; one piece is usually fixed first, whilst the other, having been cut to the required profile, is pressed tightly back into its place and fixed. A view of the back of such skirting is seen at Fig. 54.

Table or Rule Joint.—Fig. 56 is a representation of a "table" or "rule joint": a moulding of the

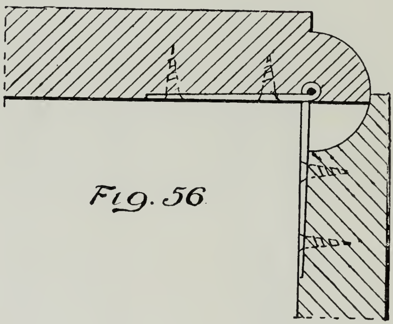


Fig. 56

ovolo type is worked upon the edge of one piece, whilst the adjoining piece is hollowed out to receive it. Back-flap hinges are used for this joint, and, when brackets are required to move backward and forward below it, the knuckles of the hinges are sunk below the surface with the flanges. The advantage of this form of hinged joint is that a moulded angle is formed when the pieces are turned at right angles with each other, and the joint has not the appearance of gaping as in the square or butt joint.

Housed Joint.—When the end of one piece of material, without being shouldered, is embedded in the surface of the other, it is said to be housed. Arris

rails usually have their ends embedded or housed into posts to secure additional strength; but the joint is more commonly used in connecting the ends of treads and risers with strings; the depth to which they are housed may be $\frac{1}{2}$ in. or $\frac{5}{8}$ in., according to circumstances, and they have the additional security of glueing, wedging, blocking, and screwing.

Joggle Joint.—This is shown at Fig. 57, and in this case represents the lower end of a wooden storey

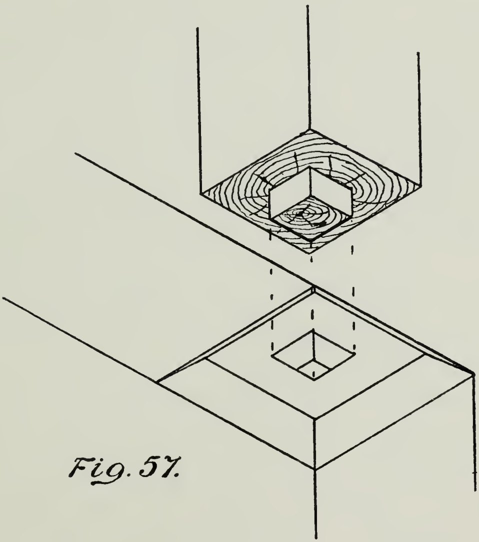


Fig. 57.

post joggled to a stone curb which has been tabled and weathered to prevent the water from penetrating the joint; it is somewhat in the form of a tenon, but cannot be considered purely as such, as it is only intended to keep the post from sliding out of position. Lower ends of solid door frames are sometimes treated

in this manner, but unless the stone base can be tabled, it is a very bad form of joint, as the water being frequently in contact with the end grain of the wood, the structure is likely to become rotten.

Dowel Joints.—This is a form of joint which often, in cabinet work, replaces tenons; small pins or dowels are driven into the prepared butt ends of a rail and corresponding holes are formed in the stiles for their reception. In another form it is seen at the bottom of solid door-frames, where they are in contact with stone floors. A square or round plug or dowel is driven into the centre of the end of the frame and a corresponding hole is made in the stonework in which it is embedded, the joint being made good in cement. Where there is a liability of water coming in contact with the joint, as in work of the warehouse class, it is advisable to have prepared a cast iron-shoe about 3 in. high, provided with a lug upon its under side: this should be fitted and made fast to the base of the frame, painting both the wood and the inside of the shoe before fixing.

Bridle Joint.—The joint between two timbers is said to be bridled when one of its pieces, instead of having a mortise cut into it, has the two outer thirds cut away, as shown at Fig. 58, its centre third remaining intact: it is supposed to give a greater abutment to the ends of struts so that they may be better able to resist the thrusts along their lengths. When, as in the case of centres, a settlement of the framing would cause a strut to take up a slightly different position, the shoulders may be curved in outline as shown at *B*, the strength of the joint not being materially weakened by the motion.

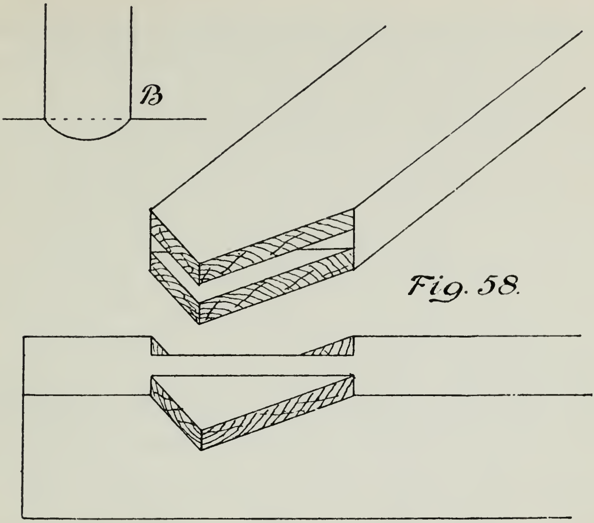


Fig. 58.

Carpenters' Boast.—This is a form of joint acknowledged more in theory than in practice, although it has

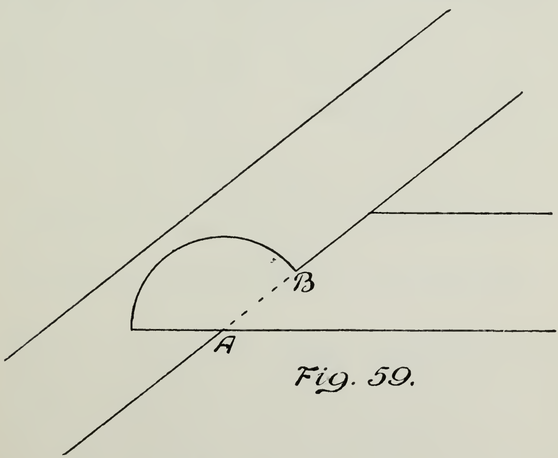


Fig. 59.

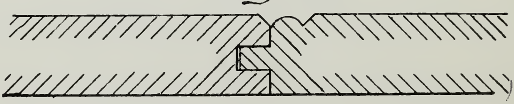
much to recommend it. It has been suggested as the joint between the collar and rafter of a roofing truss,

and forms a very good tie. Ears, in the form of a sector, are made upon one or both sides of the tie, the arc of the sector being struck from the point *A*, as shown in Fig. 59. It will be seen that no point of the ear is at a greater distance from *A* than the length *AB*, so that all that is required to place the work together is to place the rafters at right angles to the collar or tie; then, after inserting the ears so far as possible, close the tops of the rafters, and the joint is secure, without bolts or other means of fastening.

Birdsmouth.—This joint is shown at the junction of the common rafter (page 148), the ends of the timber being cut in the form of a bird's mouth, hence its name; the angle being usually a right angle, the bevel to which they are cut is taken from a side elevation of the timbers.

Matched Joint.—This name is sometimes applied to a tongue and grooved joint when the former is worked in the solid; it may or may not be provided with a bead upon the face. The section of a matched joint is shown at Fig. 60.

Fig 60.



Forked Heading Joint.—The term "heading" is applied to the joint at the ends of flooring timbers, and known, when square, as the butt joint. When the heading joint assumes the form shown in Fig. 61, it is known as forked. It is claimed for this joint that it is not so conspicuous as the plain butt joint, but the

labour involved in its formation precludes its more general adoption.

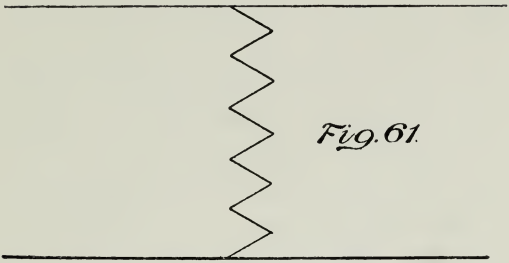


Fig. 61.

Mortise and Tenon.—Figs. 62 and 63 to 66, page 57, are representations of some of the forms of this joint;

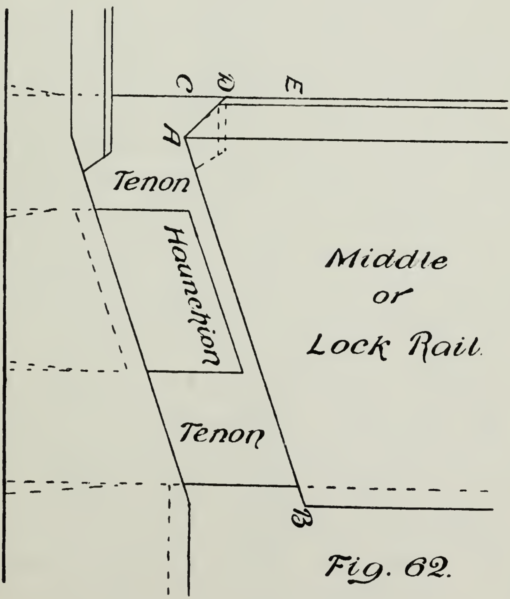


Fig. 62.

in each case the tenon has been haunched, but in its simplest form it may be constructed without it.

Tenons should be properly proportioned ; if constructed too wide in proportion to their thickness, they are apt to buckle from the pressure of the wedges, or in the case of work built up of unseasoned material the tenon is liable to shrink away from the wedges, thus losing its support; again, in thin material, if the mortise were made unduly wide, it would tend to weaken the framing by partially splitting up the work into laminations. It is advisable, in proportioning tenons, to keep their width so near as is possible five times their thickness. The thickness of tenons is largely governed by circumstances, but in the framing of doors, sashes, etc., it is a recognized rule to keep them about one third the thickness of the framing. There are, as has been intimated, departures from this rule, and Fig. 64 is an illustration of such a one ; it is known as a double tenon, and, in this case, its thickness is governed largely by the plough-groove, the inner faces of the tenons being kept flush with it whilst the remaining thickness is on each side divided in two equal parts, the tenon taking up one of them. The advantage of the preceding arrangement is that a mortise lock can be inserted without greatly diminishing the strength of the joint.

Double tenons may be applied to quartered framing where the thickness of the framing is great as compared to the width of the individual members, and where a single thick tenon placed in the centre would have its width largely diminished by the rebates. Fig. 63 shows a single tenon with haunchion. The width available for the tenon is equal to the width of the rail less $\frac{1}{2}$ in.—the depth of plough-groove—and of this a third has been

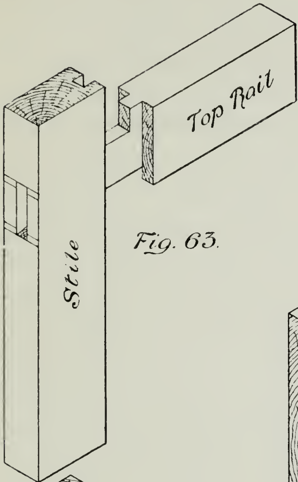


Fig. 63.

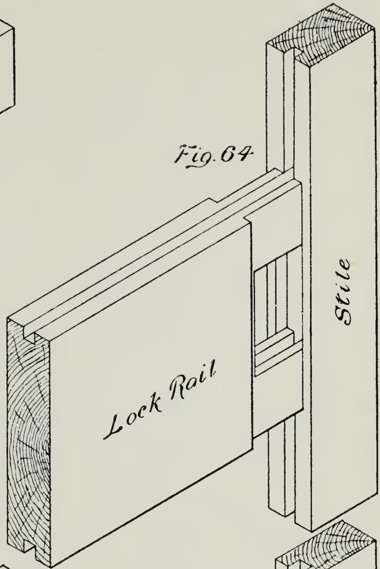


Fig. 64

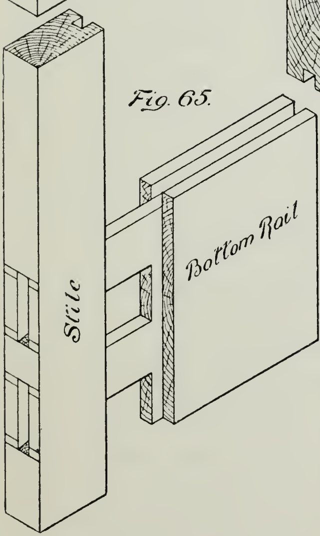


Fig. 65.

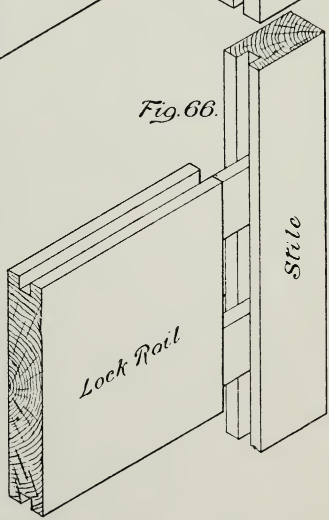


Fig. 66.

taken for the haunchion, leaving two-thirds for the tenon. In the case of the bottom rail (Fig. 65), there are two tenons and two haunchions. Bottom rails of doors are seldom less than 9 in. in width, so that deducting $\frac{1}{2}$ in. for plough-groove there remains $8\frac{1}{2}$ in. for division between haunchions and tenons. If this width be divided by four, we have $2\frac{1}{8}$ in. each for both haunchions and tenon; this should be increased proportionately with the wider rails, but is amply strong enough for the narrower ones. The available width for middle rails is necessarily reduced by 1 in., so that for a 9 in. rail only 8 in. would be available for division. It is usual to divide this width by three for the purpose of proportioning the tenon, but if this result should produce a width of tenon greater than five times its thickness it may be reduced accordingly and the difference given to the haunchion.

Gun-stock Joint.—This is the name given to the mortise and tenon joint at the middle rail of a "glass door," the stile of which has been diminished in the form of a gun-stock. This diminution of the stile makes it necessary to adopt an oblique shoulder or mitre rail; the former method frequently proves a stumbling block to the uninitiated. In placing the lines upon the rail whilst in the square, point *C*, Fig. 62, being on the edge, and representing the extended length of rail, is often taken as the point from which the shoulder-line should pass to *B*, the consequence being that when the tenons and shoulders have been cut and brought up into position the rail is found to be short at *A*. In Fig. 62, *E* has been placed square with *B*, and the distance *EC* is equal to the difference in the widths of the stile plus the depth of moulding

CA. If, in striking out, a gauge be kept of the depth *CA*, and if, from *C*, a line be squared over to point *A*, then the shoulder-line *A-B* will be the correct one. A corresponding line to this may be directly placed upon the stile, but in practice the student will find that it is best to allow a small portion of wood—say from $\frac{1}{16}$ in. to $\frac{1}{8}$ in.—to remain upon the shoulder of the stile, so that it might be protected until the mouldings are scribed, and then, having brought the rail approximately into position, cut the inclined shoulder of stile parallel to, and at the required distance from *AB*, first seeing that the rail is at right angles to the stile.

Oblique Mortise and Tenon Joints, or Bevelled Shoulder Joints.—These are represented in most of

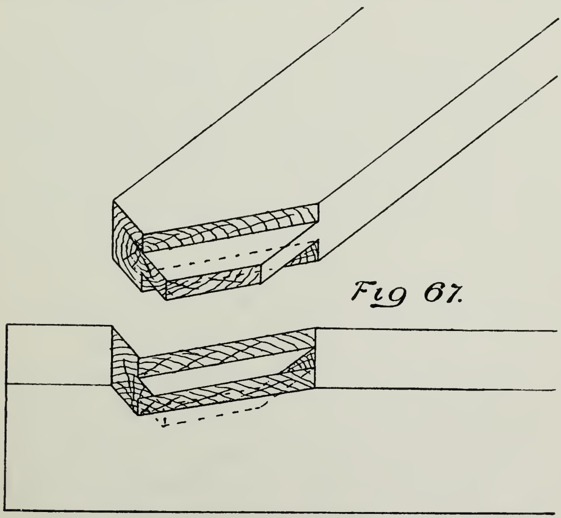


Fig 67.

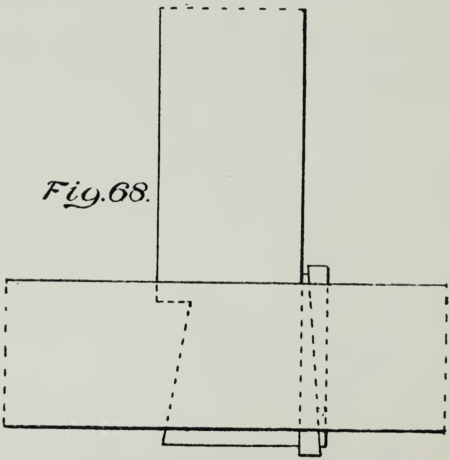
the joints of the roof trusses, and in the mortised and tenoned connection between any two members not at

right angles to one another: it is seen dissociated at Fig. 67.

Chase-Mortise.—When a tenon cannot be entered in the usual manner, a chase has to be cut at its side so that the tenon may be passed into its position from that side. The mortise so treated is therefore called a chase-mortise. Ceiling joists having to be placed in position between binders, and having their ends tenoned, require the mortises to be chased, as shown at *B*, Fig. 3, page 80.

Dovetail Mortise and Tenon.—This is a form of mortise and tenon joint much used in temporary

Fig. 68.



work. It has one of its edges recessed, so as to make the tenon of the form of a dovetail, and is secured in its position by a pair of folding wedges driven at its back: it is shown at Fig. 68. This form of dovetailing a tenon may be applied to those which do not pass through the material, and in this form is known as a dovetail stump tenon.

Bareface Tenon.—A tenon which has a shoulder only upon one side of it is known as a bareface tenon

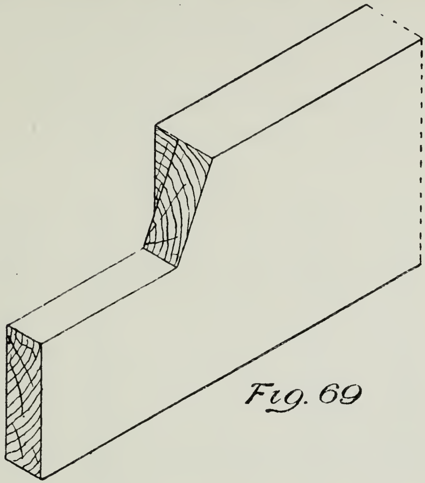


Fig. 69

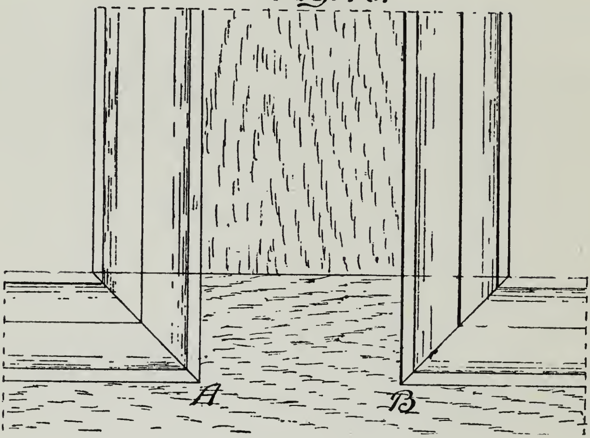
(Fig. 69). It is often used in furniture, and becomes necessary in the case of apron pieces to skylights, etc.

Stump Mortise and Tenon.—This is the name given to mortises and tenons which do not pass through the material, either from the fact that they would otherwise be carried too far, as in the case of muntins tenoned to wide bottom rails, or from the fact that the end grain of the tenon would be unsightly if allowed to appear upon the exposed edge of a piece of framing. These may be kept in position by glueing, pinning, wedging, screwing from the back, or a combination of any two or more of the foregoing.

Beaded Joint.—This is the name given to any form of joint provided with a circular-shaped moulding known as a bead, the form and utility of which is described in Chapter XI.

Masons' Mitre.—This is illustrated at Fig. 70. The framing is mortised and tenoned with the shoulders in the square, the mouldings being stopped at the mortises. After the shoulders have been fitted, the return of the moulding is worked on the solid, the lines being taken from the adjacent piece. This is the method of mitring adopted by masons, hence its name.

Fig. 70.



It is said in favour of this joint that the mitres do not open; but, as the material used by the carpenter and joiner shrinks and expands, the line of moulding may therefore be lost. This latter drawback does not occur in masonry, and may be disregarded; but for woodwork, the writer's opinion is that the shoulder line is best at *A-B*—it certainly is the shorter of the two—and the junction between the mouldings is best made at the mitre.

Clamped Joint.—Clamping is one of the means adopted for stiffening wide boards and preventing them from twisting. The material should be thoroughly well

seasoned before putting together, otherwise it will be found to split in drying. Narrow pieces called clamps are mortised and tenoned to the ends of a board, as at Fig. 71, and may be plain as at *A*, or mitred as at *B*.

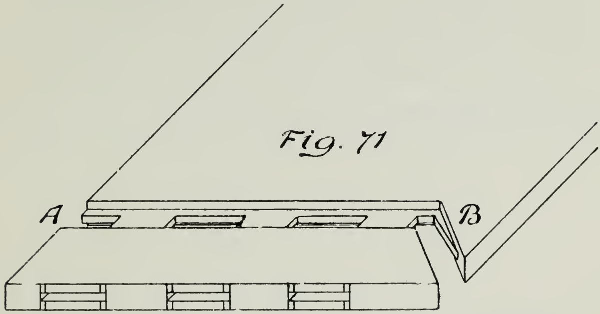


Fig. 71

The latter is known as mitre clamping, and is necessary in desk tops, etc., where mouldings have to be returned on the edges, or where the appearance of the end grain on the material would be objectionable. The tenons may or may not pass through the clamps.

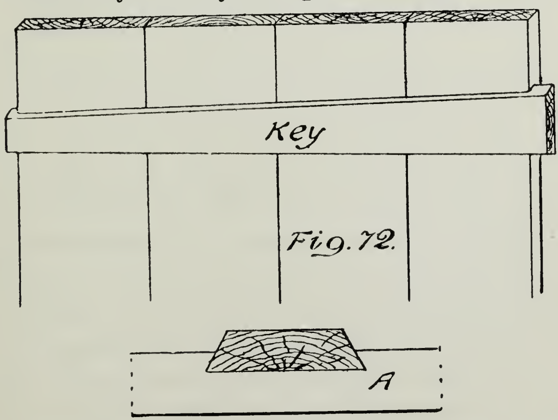


Fig. 72.

Wide boards not otherwise framed may have dovetail keys let into the back of the material, as in Fig. 72,

to prevent them from warping, and the key may be planed off flush with the surface, or left standing as in the figure. An enlarged section of the dovetail key is shown at *A*, Fig. 72. It is advisable to allow the wide end of the key to remain, if possible, so that any looseness caused by the shrinkage of the material may be met by a blow or two upon that end.

Foxtail Wedging.—This is the name given to the method of wedging stump tenons, as shown in Fig. 73.

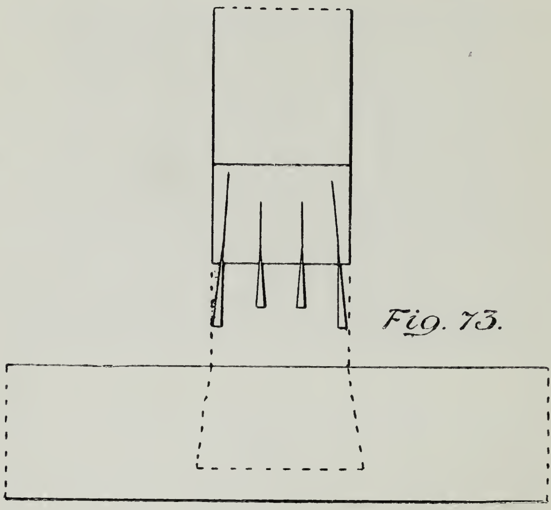


Fig. 73.

The mortises should be made no longer at the top than is necessary for the admission of the tenon, whilst the ends are sloped away towards the interior; saw kerfs are then made through the tenon, those towards the outside being sloped inwards, so that the edges of the material may not be split. Small wedges are then inserted in the saw kerfs, and the tenon driven into position; as the end of the tenon reaches the base of

the mortise the wedges are pressed into the kerfs, widening the end of the tenon and preventing it from being withdrawn.

Safe Wedging.—With plain wedging, the material, upon shrinking, sometimes parts from the tenons; more especially is this the case with exterior work, the joints of which have been painted instead of glued. To prevent this, saw kerfs should be made through the

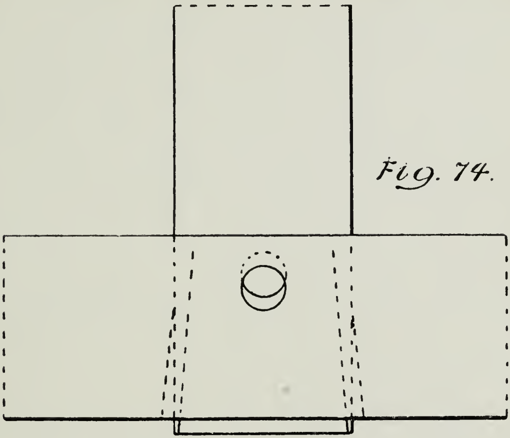


Fig. 74.

tenons, as shown at Fig. 74, allowing the kerf to recede from the side, as the shoulder is approached. If the wedges are driven into these kerfs, instead of at the sides of the tenon, the framing is rendered more secure.

Pinning.—This is the process of securing a tenon by the insertion of a pin through both mortise and tenon. The joints of the main timbers of partitions, and in fact all "quartered" work, should be treated in this manner, unless secured by bolts, etc. The pins used in work of this description are sometimes called

"treenails," but the term is more common to shipbuilding localities.

Drawbore Pinning.—This is another form of the foregoing. In this case the material containing the mortise is first bored through in a position near the shoulder—keeping the pin-hole at a clear distance from the shoulder equal to one and a half times the section of the pin—then, having inserted the tenon, mark the centre of the hole upon the tenon by the aid of the "bit," first seeing that the shoulders are in position. After withdrawing the tenon a hole may be bored through it, and nearer the shoulder to the extent of nearly half the section of the pin. When framing up the work it may be found necessary to use a steel drawbore pin for the purpose of closing the shoulders, after which the wooden pins may be inserted, first covering them with paint or glue. Pins used for this work should be split, so that the grain may run through their length and not obliquely across, as is sometimes the case with those sawn.

Secret Nailing.—This may be accomplished, as shown at Fig. 75, and may be adopted in all cases

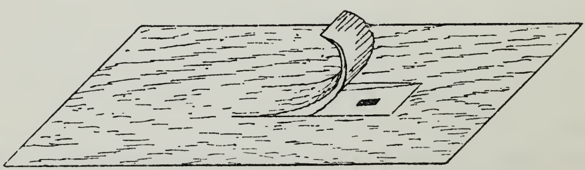


Fig. 75.

where the wood is coarse grained or of a porous nature, such as oak or teak. In fixing dado framing, etc., it is sometimes necessary to nail through the framing

from the face; a small portion of the grain is lifted with a thin $\frac{1}{4}$ in. or $\frac{3}{8}$ in. chisel, and the nail driven beneath it; the material is then glued and replaced. Another form of secret nailing, as distinguished from face nailing, is adopted in fastening floor-boards. In this case the nail is driven through the edge of the board in an inclined direction, the next board is then brought into position and treated in a similar manner. The edges of the boards being matched, it only requires that one shall be fixed to keep both down, whilst the boards, being fixed at one edge only, are free to shrink and expand with the changes of temperature.

Secret Screwing.—Fig. 76 represents a method of further securing the glued joints of work exposed to

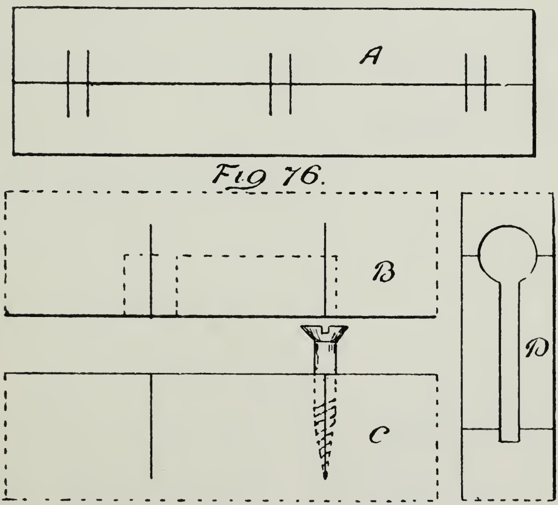


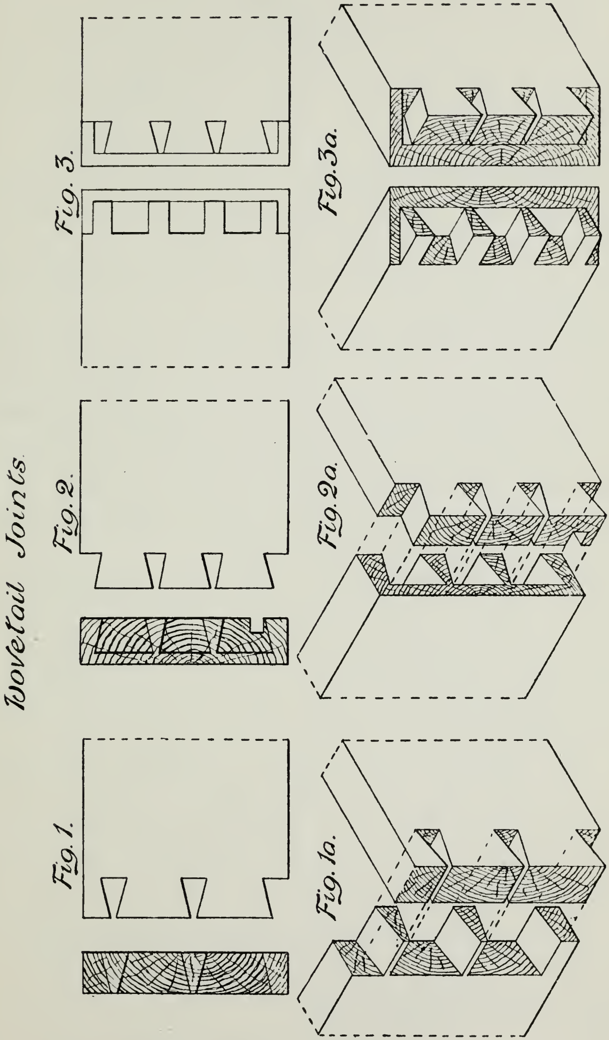
Fig 76.

the weather, by embedding screws along the length of the joint. The method of procedure is as follows: The boards having been jointed in the usual way are set

up in the vice, and parallel lines marked across the joint in pairs and at intervals of about 2 ft. The distance between the parallel lines should be from $1\frac{1}{2}$ in. to 2 in., but must be equal throughout: in order to secure this, it is well to take a slip of wood with parallel edges and of the required width, and, having laid it across the joint in the required position, pass the pencil along its edges. The top piece having been removed, a stout $1\frac{1}{2}$ in. or 2 in. screw is inserted in the centre of the joint and at the rear line, as shown at *C* in the figure: a hole large enough to receive the head of the screw is then bored in the centre of the edge of the top board and at the forward line; from this hole a slot is cut large enough to receive the shank of the screw, and back to a little beyond the rear line. A view of one of these sockets is shown at *D*, Fig. 76, whilst an enlarged elevation of the joint at the lines is shown at *B* and *C*.

Splayed Heading Joint.—It is a difficult matter in laying floor boards to pull up the butt joints, and the method of closing them more generally adopted is to cut them sloping or splayed, the top edge of the last board laid being left long, whilst the first board is cut to the reverse of this. This arrangement allows the board to slide down into its place, the nailing of the board completely closing the joint.

Common Dovetail.—Of the dovetail joints there are several kinds; but the three shown on page 69 are the most important. Fig. 1 represents an end elevation of the pins and side elevation of the sockets of the common dovetail; the sloping side of the pin is pitched at about 80°, and should be from one-sixth to one-eighth the thickness of the material at its thin


Dovetail Joints.
Fig. 1.
Fig. 1a.
Fig. 2.
Fig. 2a.
Fig. 3.
Fig. 3a.

edge. Pins should not be placed nearer the edge than half the thickness of the material, although this difficulty may be overcome, should the necessity arise, by placing the half pin at the extreme edge. A better idea of the form of the joint may be gained from Fig. 1A.

Lap Dovetail.—Figs. 2 and 2A (page 69) represent the lap dovetail; the advantage gained over the common dovetail is that the end-grain appears only on one side. For this reason it is used at drawer fronts and in similar positions.

Secret, or Mitre Dovetail.—This is shown at Figs. 3 and 3A (page 69); it is a form of joint not so strong as the foregoing, as the dovetailing extends only to a portion of the thickness of the material. Its advantage is that the end-grain of the dovetails do not appear upon the face of the work, a mitre line being all that is visible, hence its name.

Flooring Joints.—Figs. 1 to 8, page 71, illustrate various sections of floor boards. Fig. 1 is a representation of a dowelled joint, the boards being secret nailed through its vertical edges, the fastening of one being sufficient to secure the other. Fig. 2 is a section through ploughed and tongued flooring, the tongue being in this case of wrought iron; a better method than this is to rebate the flooring, placing the tongue at the bottom, as, in the repair of sections, the tongues must be left out. Figs. 3, 4, 6, 7, and 8 are other forms, but the splayed joints are a disadvantage from the fact that when worn in places they exhibit an irregular and unsightly line.

Fig. 5 is an illustration of a double dovetail slip feather more suitable for block flooring than for battened.

Joints.

Fig. 1.

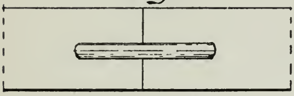


Fig. 2.

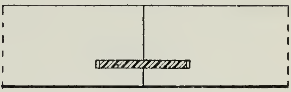


Fig. 3.

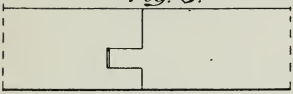


Fig. 4.

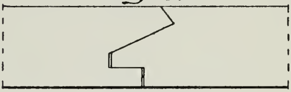


Fig. 5.

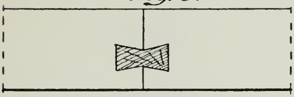


Fig. 6.

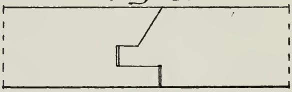


Fig. 7.

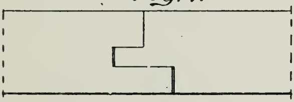


Fig. 8.

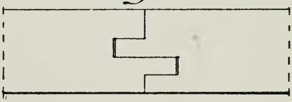


Fig. 9.

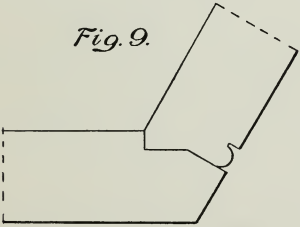


Fig. 10.

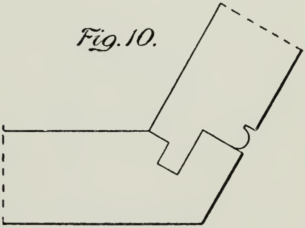


Fig. 11.

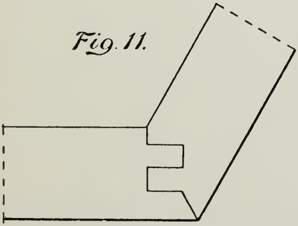
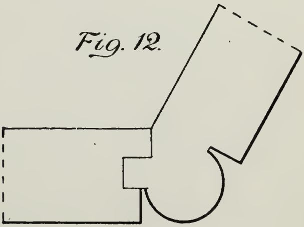


Fig. 12.



Figs. 9 to 12, page 71, and 1 to 12, page 73, are illustrations of various joints made up of a combination of the foregoing and named accordingly. They are suitable for the vertical angles of dado framing and casing generally.

Joints.

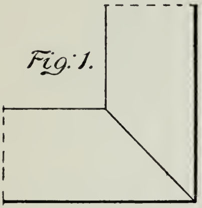


Fig. 1.

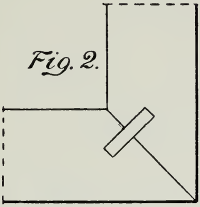


Fig. 2.

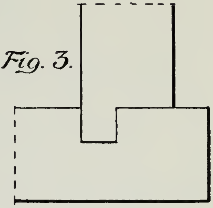


Fig. 3.

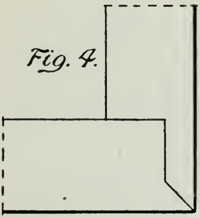


Fig. 4.

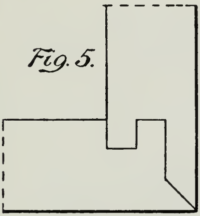


Fig. 5.

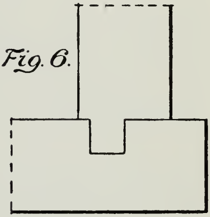


Fig. 6.

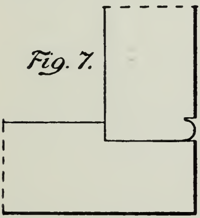


Fig. 7.

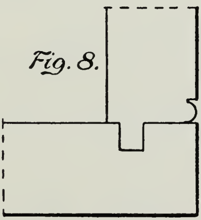


Fig. 8.

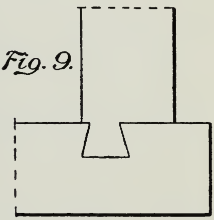


Fig. 9.

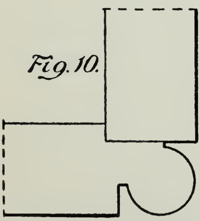


Fig. 10.

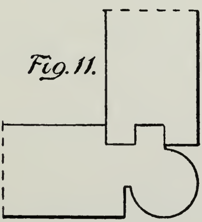


Fig. 11.

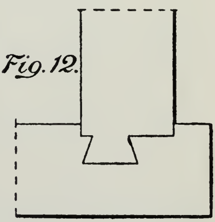


Fig. 12.

CHAPTER IV.

FLOORS.

A FLOOR may be described as that portion of a building which separates or divides the structure into stories or flats. They may be of wood, a combination of wood and iron, or, as is now often the case, especially with buildings of the warehouse class, of hard and incombustible material, rendering the floor fire and water proof. To discuss the latter class would be beyond the scope of the present work.

The term "ground floor" is applied to that which is nearest to, or is approached directly from, the adjoining street level. The floors above this are known as first, second, or third floors respectively as they range upwards, whilst those below are known as basement floors. The whole of the series enumerated above are known also as main floors, whilst those not passing throughout the building, or not upon the same level as the main floors, are known as "mezzanine floors."

The floor boarding, or that portion upon which the foot rests, although in itself a subject for which much consideration is required, is not by any means the most important point to consider in building up a system of flooring. It is to the design of the framework beneath

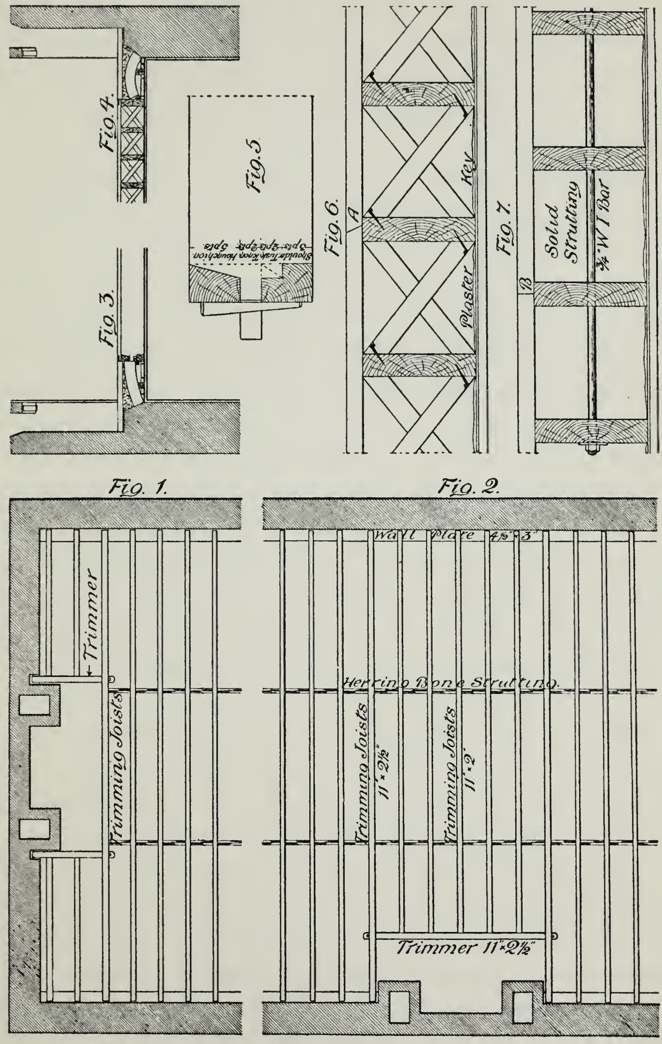


Fig. 4.
Fig. 3.
Fig. 5
Fig. 6.
A
Key
Plaster
Fig. 7.
B
Solid Strutting
¾" W I Bar
Fig. 1.
Trimmer
Trimming Joists
Fig. 2.
Wall Plate 4½"×3"
Herring Bone Strutting.
Trimming Joists 11"×2½"
Trimming Joists 11"×2"
Trimmer 11"×2½"

that the greatest amount of attention is required. The timbers which go to make up the supporting framework are known as naked timbers, both as regarding the timber previous to receiving its covering and in the consideration of the timbers apart from such covering.

There are three distinct systems or methods of building up flooring timbers, and it is the strength of such floor and the economical disposition of the material that are the primary considerations in the selection of the particular system to be adopted.

Single Flooring.—This is the simplest kind of flooring constructed and is suitable only for small spans up to 14 or 16 feet. Horizontal timbers called joists, 8 in. to 11 in. deep, are placed parallel to and at distances from each other of about 12 in. centre to centre, and rest with their extremities upon wall plates, usually $4\frac{1}{2}$ by 3 in., passing along the entire distance covered by the ends of the joists. It is upon the upper edges of the joists that the flooring boards are fixed, whilst to the lowest edges the ceiling is attached.

Figs. 1 and 2, page 75, represent two plans of portions of single floors, the clear span in each case being 16 ft., the largest span advisable with this form of floor. Two rows of strutting have been placed at regular intervals along the joists; these stiffen the joists considerably. The two plans are given to illustrate the method of treatment of the timbers, both when the fireplace is parallel with, and also when at right angles to, the joists. Timbers may not be built into flues surrounded by $4\frac{1}{2}$ in. brickwork, it therefore becomes necessary to trim the timbers short of the chimney

breast. This trimming permits the flooring in and around the fireplaces to the extent of 18 in. in either direction to be built of hard and incombustible material, such as brick, stone, and concrete. Trimmer arches, as shown in the sections at Figs. 3 and 4, are built between the trimmed timbers and upon these hearth stones are laid, embedded in concrete and cement.

In Fig. 1, page 75, the joists run parallel to the wall containing the fireplace; a trimming joist is placed eighteen inches from the chimney breast, and into this are tusk-tenoned two short trimmers, carrying in their turn the ends of the trimmed joists. It is usual to increase the thickness of trimming joists one-eighth of an inch for each trimmed joist carried, and to make the trimmers of the same thickness. All joists, common or otherwise, should rest either upon wall plates or stone templates in pockets; illustrations of the latter are given on page 84, Figs. 1 and 2.

Fig. 2, page 75, is a portion of a plan of a single floor, the common joists here running at right angles to the wall containing the fireplace. Two trimming joists rest on the ends of wall plates, one on either side of the chimney breast, with a clear space for a rendering coat between the timbers and flue. At a distance of eighteen inches from the breast-line a trimmer is placed in position, being tusk-tenoned at either end to the trimming joists, whilst to the trimmer all the intervening joists are trimmed; the latter are therefore termed "trimmed joists." As in the previous example, the trimming joists are increased in thickness to the extent of $\frac{1}{8}$ in. for each joist carried by it. In this case there are two and a half joists carried by each trimming joist, and as $2\frac{1}{4}$ in. joists would be in-

sufficient, the next larger size is used, namely $2\frac{1}{2}$ in., and the trimmer made accordingly of $2\frac{1}{2}$ in. material.

Double Floors.—Floors, the main timbers of which are composed of either of the following combinations, are known as double floors, plans and sections of which are contained on page 80.

(1) Floor joists with ceiling joists, a section of which is shown at Fig. 2, page 80.

(2) Common joists with binder, as shown at Fig. 77.

(3) Floor and ceiling joists with binders, as given in section at Figs. 1 and 4, page 80.

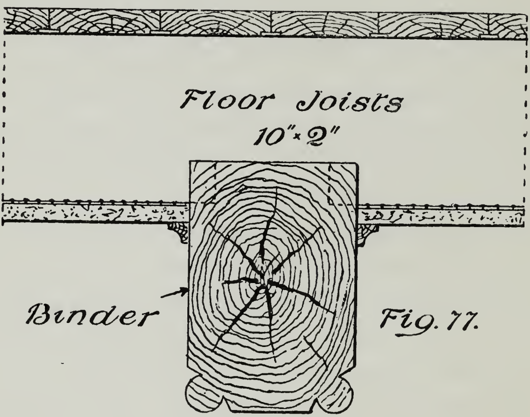


Fig. 77.

Double floors may be constructed as such for two distinct purposes.

(1) For the purpose of preventing the passage of sound.

(2) For the purpose of economically increasing the strength and rigidity of a floor when the span is greater than would be recommended as a single floor.

Prevention of the Passage of Sound.—The vibration and noise caused by the passage across floors is often an objection in a great many cases. To prevent this the following schemes have been devised.

Sound Pugging.—This is shown at Fig. 78, and consists of placing a series of short boards—called

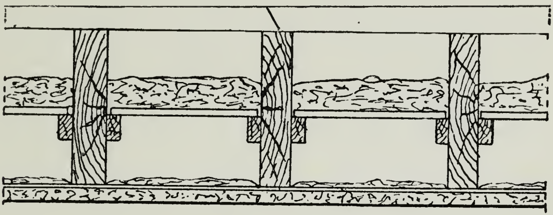


Fig. 78.

sound boarding—across the opening between the joists and about mid-way between the floor and ceiling: these rest loosely upon battens nailed to the sides of the joists, and upon it is placed, to the depth of about 2 in., builders' lime rubble. It is found that by interposing several bodies of different densities, the passage of sound is rendered more difficult.

Another method of reducing vibration is to make every fourth or fifth joist deeper by about 2 in. than the remaining ones; this is shown at Fig. 2, page 80. Ceiling joists are then added, notching and spiking them to the deeper joists. This is known as a double floor, and is designed more for the purpose of preventing the passage of sound than of increasing the strength of the floor. It has been recommended that floor joists should not greatly exceed twelve or fourteen feet in length, or they become liable to excessive vibration, causing the plaster ceiling to

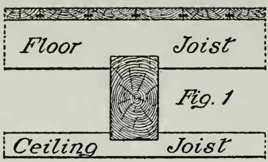


Fig. 1

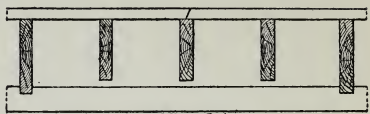


Fig. 2

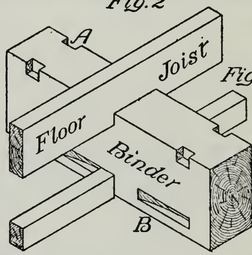


Fig. 3.

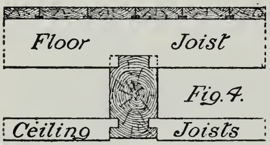


Fig. 4.

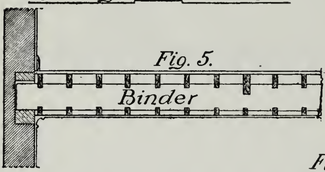


Fig. 5.

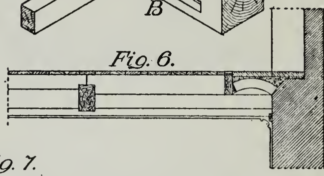
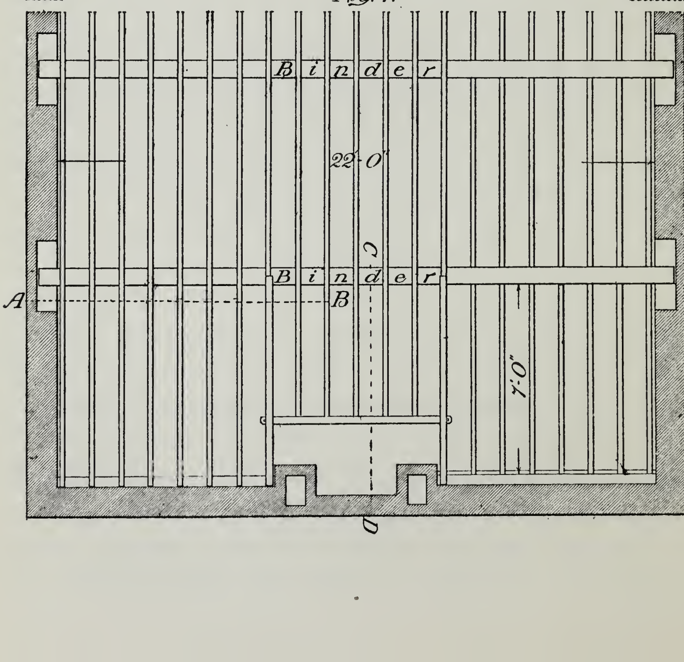


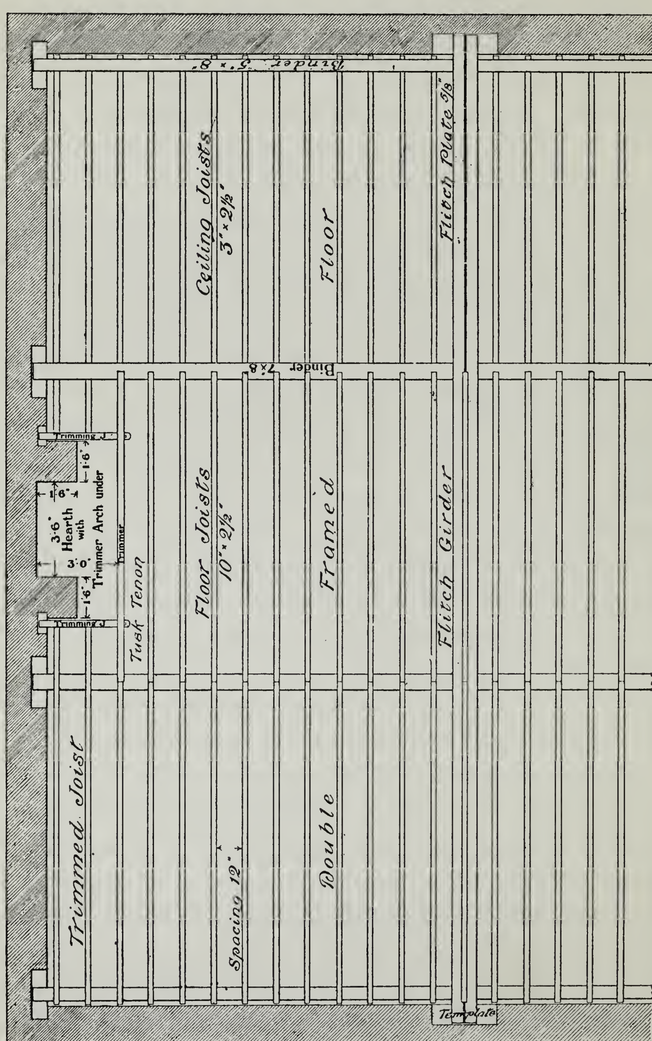
Fig. 6.

Fig. 7.



crack and become unsightly; it therefore becomes necessary, in spans greatly exceeding these dimensions, to diminish the distance by dividing the floor into "bays," placing binders between, as shown at Fig. 7, page 80. In this case the least distance between the walls is 22 ft., whilst in the other direction it is 23 ft. It will be seen that the single flooring could not be applied in this case. Two 12 in. by 7 in. binders, having a clear span of 22 ft., are placed from wall to wall, resting at their ends on stone templates and in wall pockets specially constructed. As in the last example, the ends of all timbers are kept clear of the walls, and constantly in contact with a fresh supply of air. The line parallel to the wall plate at Fig. 7 represents a cleat fastened to the surface of the wall, to which is made fast the ends of the ceiling joists, the method of trimming round the fireplace being the same in plan as in the last example, whilst sections through *A—B* and *C—D* are shown at Figs. 5 and 6 respectively. Sections across the binders are shown at Figs. 1 and 4, either one being applicable. An isometric view of the detail of Fig. 4 is shown at Fig. 3, giving the detail of the cogging at *A* and that of the chase mortice at *B*.

Double Framed Floors.—When both the length and breadth of a floor space are so great that if binders alone were used they would require to be of such dimensions as would cause the framing to be of unnecessary expense, as in the example given on page 82, girders and binders are rendered necessary. In that case the larger and more important timbers are framed together, hence the name "double framed floor." The larger span is divided up into two or more "bays" by placing girders across the shorter span and


Binder 5"×8"
Ceiling Joists
3"×2½"
Floor
Flitch Plate 5/8"
Binder 7"×8"
Trimming J
1'6"
3'6"
Hearth
with
Trimmer Arch under
3'0"
Trimmer
Tusk Tenon
Floor Joists
10"×2½"
Framed
Flitch Girder
Trimming J
Trimmed Joist
Spacing 12"
Double
Template

at a distance from one another, not less than sixteen feet, but usually about twenty. Into these latter, binders are framed, at distances from each other ranging from eight to fifteen feet, and upon these the joists are carried. In the illustration given on page 82, a little more than a third of the plan of a double framed floor is given, the clear spans in length and breadth being 46 ft. and 34 ft. 3 in. respectively. The longer distance has been divided into three smaller spans by placing two flitch girders across in such a position as to divide it into three equal "bays." Into these, binders are framed, dividing the smaller span also into three equal bays, whilst upon them the flooring and ceiling joists are carried. The flooring joists are shown in the two top "bays" resting upon the tops of the binders, whilst on the top of the flitch girder is placed a furring piece, the top edge being in line with that of the floor joists.

Fig. 3, page 84, represents a section through the girder of such a floor; in this case the whole of the floor timbers are hidden between the floor and ceiling, and greater head-room is given. The girders in Figs. 3 and 4 are sawn into half timbers called flitches, and the wrought-iron flitch-plate inserted between them, being bolted, as shown in section, by the dotted lines of Figs. 3 and 4, and in elevation as at Fig. 5. This gives an opportunity to reverse the timber, thus equalizing the strength throughout its length and minimizing the weakness caused by the local defects, such as large knots, twisted fibre, etc.

Flitch plates should in no case be of the full depth of the timbers, but should finish $\frac{1}{2}$ in. within the top and bottom surfaces; otherwise, as the timber shrank,

Fig. 1.

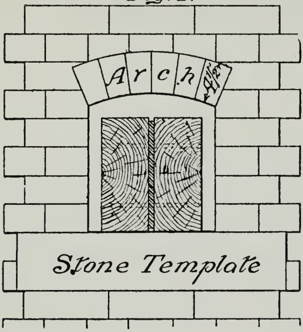


Fig. 2.

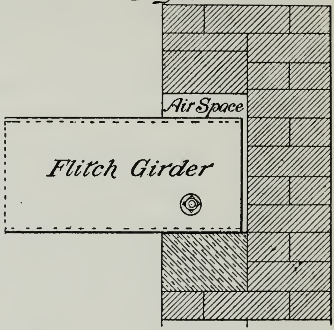


Fig. 3.

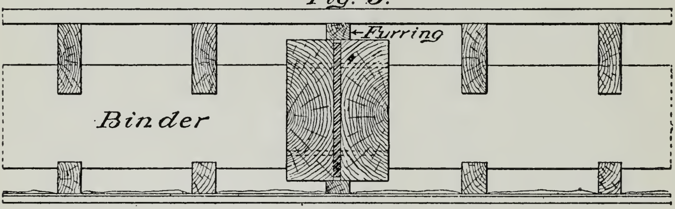


Fig. 4.

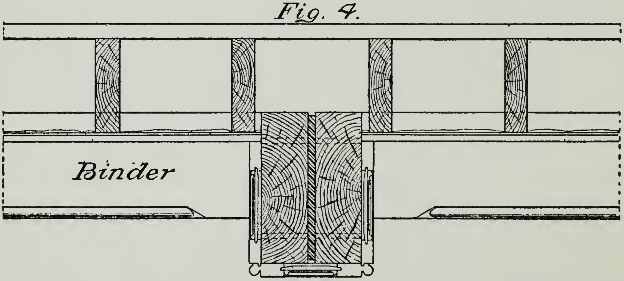
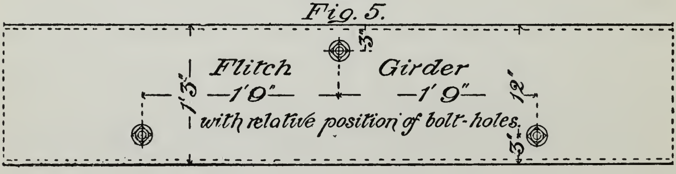


Fig. 5.



or by the unequal resistance of the material, the narrow edge of the metal plate would form a knife-edge and, bearing alone upon the template, tend to create a fracture. Timber, in being fixed, should have the heart exposed to the air, as it is that part that is most liable to decay. In Fig. 3, page 84, the hearts are exposed and the outer rings placed in contact with the metal plate.

Large timbers should under no circumstances have their ends built into walls. In the case of some of

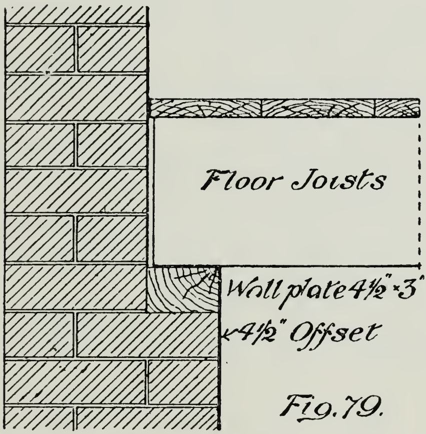


Fig. 79.

the softer and more porous bricks, they are known to absorb nearly their own weight of water. This, in damp houses, or buildings erected without proper damp or ventilating courses, would be readily taken up by the absorptive nature of the woodwork, and the most important part of the timber—its bearing surfaces—would at once be liable to decay. In building houses of several stories, the walls at the base would

of necessity be of greater thickness than at the top: this diminution usually takes place at ceiling level, and in offsets of $4\frac{1}{2}$ in. The offsets may be utilized for the purpose of supporting wall plates ($4\frac{1}{2}$ in. by 3 in.), upon which the ends of joists may rest and the necessity of building them into walls would be reduced (see Fig. 79). Should no offsets occur at convenient places, the brickwork may be corbelled out as shown

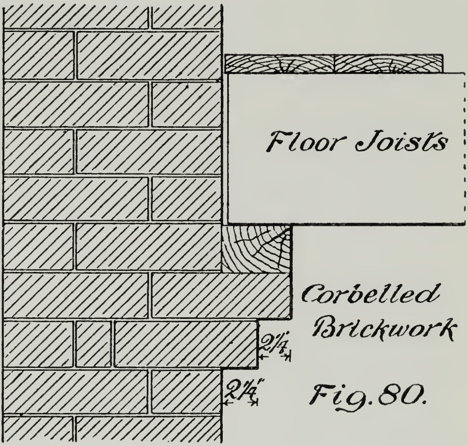


Fig. 80.

at Fig. 80. These will not be conspicuous, as in most cases the cornices cover them. Should the former methods however not be practicable, small 'pockets' should be provided in the walls slightly larger than the section of the material, so that the air may be able to pass in and around the ends.

Wall plates, if built into walls, should be looked upon with suspicion, as they are likely, by shrinking or rotting, to cause the wall to lose its support and thus tend to overturn it.

Timbers resting on, or embedded within walls should be thoroughly dry and have their surfaces coated with bituminous or other material impervious to moisture.

When large timbers, such as beams, binders, or girders, rest within walls, 'pockets' should be provided as shown in elevation and section at Figs. 1 and 2, page 84, support being given to the wall above by means of a $4\frac{1}{2}$ in. brick arch, or a stone lintel—sometimes called a "Derby"—of a thickness equal to one or two courses of brickwork and supported at its extremities to the extent of $4\frac{1}{2}$ in.

Basement Floors.—The joists of basement floors rest at their extremities upon wall plates, as described above, and, at intervals along their length, upon plates carried by sleeper walls resting directly upon the foundations and provided with damp courses: these latter should be below all timbers and at least 6 in. above the surrounding soil. No trimmers are necessary here, as the hearth stones are carried upon walls at least 9 in. thick and known as "fender walls." These latter not only carry the extremities of the hearth stones but also the ends of the joists, wall plates being provided as in other cases.

Ventilation of Basement Floors.—The wood-work of basement floors is subject to the damp arising from the soil, and this, when combined with heat generated by kitchen ranges, etc., usually located in basements, is favourable to the growth of fungi which feed upon the moist wood-work, causing its destruction. To prevent this, the air beneath the floors should be subject to constant change so that it may be kept as fresh and cool as the surrounding atmosphere: this is best accom-

plished by perforating all sleeper walls and creating in the others ventilating courses of vitrified and perforated brick-work. These latter not only act as ventilating courses but, being vitrified, are impervious to moisture, preventing it from rising to the main body of brick-work.

CHAPTER V.

PARTITIONS.

PARTITIONS are the constructions by which the various stories or flats of a building are divided into their several compartments. Besides those which the main walls of a building supply, and which range upwards throughout the entire series of floors, the following may be considered:

(1) Studded Partitions.
(2) Bricknogged Partitions.
(3) Trussed or Quartered Partitions.

The following is a description of some of the parts employed.

Studs.—These are the vertical members of a lath and plaster partition, upon the edges of which are nailed the laths; they are usually 2 in. wide and of a thickness equal to that of the main timbers, from $4\frac{1}{2}$ to 6 in. When the studs are cut short, as over the heads of doorways, they are termed "puncheons."

Framing.—The assemblage of main timbers upon which the partition depends for its strength.

Wall Posts.—The vertical pieces of framing adjoining the wall and passing from sill to head.

Sill.—The lowest horizontal member of the framing,

the piece into which the lowest ends of the studs are fixed.

Head.—The highest horizontal member of the framing.

Struts.—The inclined pieces which carry the load from central to lower positions, and in such a manner that the thrust is first received by horizontal ties. They are sometimes termed "braces."

Interties.—These are horizontal members of the framing, passing from wall to wall, usually at the head of the doorway, and providing an extra tie in cases of necessity. Sometimes the door posts pass without interception from sill to head; in such a case, the door head is tenoned to the posts at a convenient height. This method is not recommended for the heavier classes of work.

Nogging Pieces.—These are small horizontal pieces notched to the studding at vertical distances of about 4 ft., and are intended to stiffen the studding.

Studded Partitions.—These are common partitions usually erected after a building has been completed; they are not self-supporting, but usually rest upon the floor. The head and sill are placed in position, and between these are placed studs stump-tenoned to the head and sill, usually 4 in. or 4½ in. by 2 in., provision, of course, being made for doorways, borrowed lights, etc. No strutting is here employed, but nogging pieces should be used at vertical distances of about 4 ft. for the purpose of stiffening the studding. In some classes of work studded partitions are boarded on one or both sides in place of the lath and plaster.

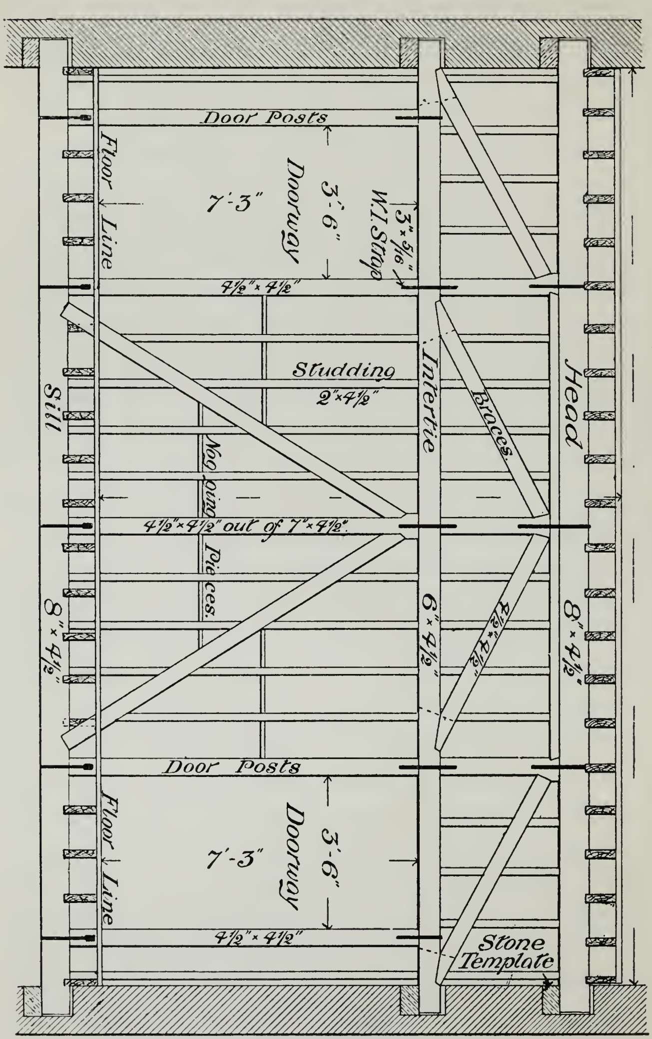
Bricknogged Partitions.—These are, practically, 4½ in. brick partitions strengthened at frequent

intervals by timber studding. These should range vertically at distances equal to the multiple of half a brick, so as to avoid unnecessary cutting and the consequent waste. Partitions filled in in this manner, and plastered, are considered to be warmer than when left hollow; the position should be dry and the wood-work thoroughly seasoned and coated, otherwise dry rot will attack the timber-work and render it useless.

Trussed or Quartered Partitions.—These are the most important of the timber partitions. They may be made not only self-supporting, but may be constructed to support either the floor or ceiling, and, in some cases, to support both floor and ceiling. The illustration given on page 92 is that of a trussed partition, constructed to support both floor and ceiling, and is intended to show how the various parts of the framing may be disposed.

The most important principle that one should bear in mind in framing trussed partitions, is to economically dispose the timbers in such a manner that the weight is brought vertically upon the walls. In order that this may be properly accomplished, struts or inclined braces should be connected directly to the horizontal ties, such as the sill or intertie, and not to wall posts. The latter, being usually only stump tenoned to the ties, are least capable of withstanding the thrust.

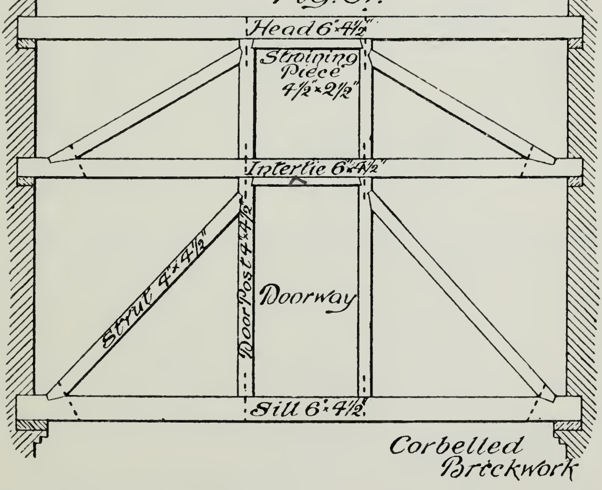
The sill, in the illustration given on page 92, lies below the level of the bottom of the floor joists, and may be cased similar to a binder. If this is objectionable, the sill may be arranged within the level of the flooring; this is more convenient when the joists are parallel to the sill. Where a series of such partitions are required in a direct line up through a


Door Posts
Floor Line
7'-3"
Doorway
3'-6"
3"×5/16"
W.I. Strap
4½"×4½"
Studding
2"×4½"
Sill
8"×4½"
Nogging Pieces
4½"×4½" out of 7"×4½"
Intertie
6"×4½"
Braces
4½"×4½"
Head
8"×4½"
Trussed Partition.
Door Posts
Floor Line
7'-3"
Doorway
3'-6"
4½"×4½"
Stone Template

building, they may be arranged so that the head of one becomes the sill of the next above; or the intertie may, if the rooms are not lofty, supply the place of the head of the lower portion and sill of the upper. In some partitions the doorways are made extremely wide for the reception of folding doors; in this case the door-head should be supported at intervals by means of bolts passing upwards to the head of the partition.

The horizontal timbers of framed partitions should be let into the walls at either end; additional support may be rendered by means of stone corbels, or the brickwork itself may be corbelled out to receive the framing, as shown in Figs. 81 and 82.

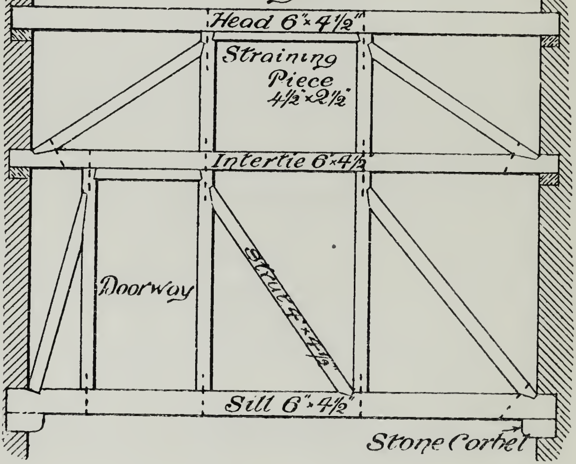
Fig. 81.



Figs. 81 and 82 represent two other forms of trussed partitions, the doorways being in the centre and at the side. The heads, interties, and sills being $4\frac{1}{2}$ in. by 6 in., the braces and posts $4\frac{1}{2}$ in. by $4\frac{1}{2}$ in.,

and the straining pieces $2\frac{1}{2}$ in. by $4\frac{1}{2}$ in. The diagrams represent the principal trussing only, the studding being left out. The position of the necessary bolts and straps are indicated by dotted lines. Details of the joints are shown in Chapter III.

Fig 82



Brandering or Counterlathing.—When wide timbers are employed in trussed partitions, their surfaces should be counterlathed or brandered, as it is sometimes called, so that the plaster may be keyed to their surfaces. Laths are first nailed across their width, and others nailed upon them at right angles, thus permitting the plaster to pass in behind.

Laths.—The laths used for plastering purposes are of three thicknesses, viz.:

Lath,	- - - -	$\frac{3}{16}$ in. thick.
Lath and half,	- - -	$\frac{1}{4}$ in. ,,
Double Lath,	- - -	$\frac{3}{8}$ in. ,,

The scantling of partitions generally may be inferred from the sizes already furnished. It would be impracticable to furnish a table of sizes, as these would differ materially with the design; the student will be able, by the aid of statics, to determine the stresses in the various members of a particular design, the weight generally being taken as from 13 cwt. to 15 cwt. per square when covered.

Fig. 83.

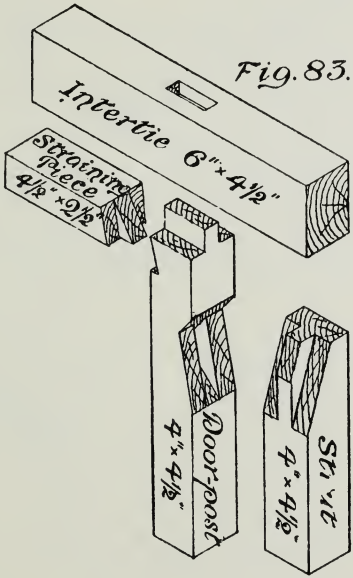


Fig. 83 represents the joints around the door-head of the partition given in Fig. 81; the joints are here dissociated, so that their forms may be readily seen, whilst the strut has been moved from its position for the same purpose.

Figs. 84 and 85 represent two forms of nogging pieces and the mode of fixing; besides being notched

to the studding, they should be nailed. Sometimes, in common work, nogging pieces are cut clear of the studs, the only fastening they receive being by nailing.

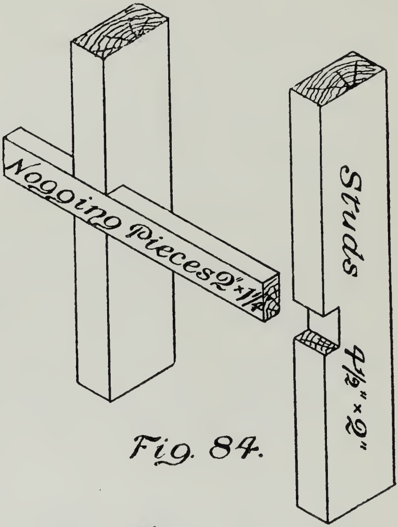


Fig. 84.

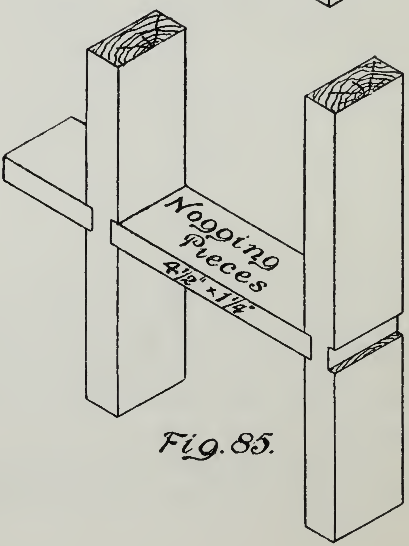


Fig. 85.

CHAPTER VI.

DOORS, DOOR FRAMES, AND LININGS.

THE construction of the work described in this chapter may be considered as forming one of the chief items in the occupation of the joiner, and, although considered chiefly from a point of utility, may be made to lend itself, in some cases, to elaborate architectural treatment, both with regard to exteriors as well as interiors.

It is intended in this work to describe only the plainer varieties, having in view their construction under ordinary circumstances.

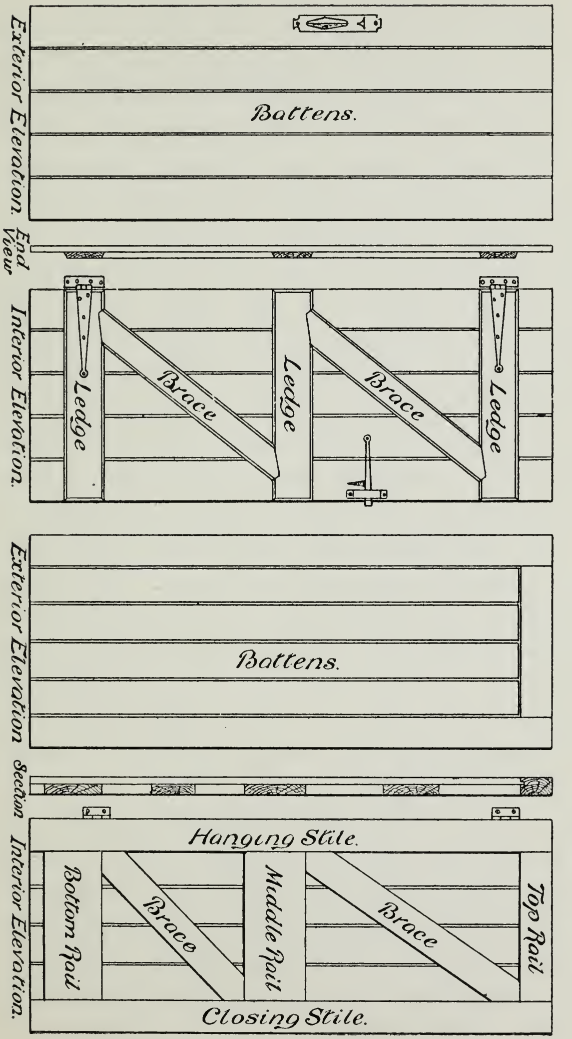
Battened Doors.—In this series may be considered the following: Ledge doors; ledged and braced; framed and battened; and framed, battened, and braced, the latter being sometimes termed framed and braced.

Ledge Doors.—This is the commonest variety of door, and chiefly used in outhouse work. It is constructed by fastening a series of battens (grooved and tongued) together by means of horizontal ledges nailed, or nailed and screwed, to them. In the better class of work the ledges are fastened to the two outer battens by means of two screws at each of their ends, whilst the intermediate battens are simply nailed; the latter should

be of steel or wrought-iron, and should pass through both ledge and batten, and have their points turned at the back; this process is known as clinching. As the battens shrink away from each other, they loose their support; and the nails not being sufficient to support them, the door drops at its closing edge.

Ledged and Braced Doors.—In order to prevent the ledge door from dropping at its closing edge, braces are placed obliquely from ledge to ledge, passing upwards from the hanging to the closing edge. These act as struts, preventing the outer edge of the door from dropping. As the struts or braces are always in compression, all that is required at the points of support is a plain butt joint, a portion of which should be at right angles to the direction of the brace. As with the ledges, the braces are kept in position by nailing, the points being clinched as in the former case. Page 99 contains an exterior and interior elevation of a ledged and braced door. The hinges and latch have been placed in position mainly for the purpose of indicating the direction to which the braces should incline.

Framed and Braced Doors.—This is the best form of the battened doors, and when not braced it is usually termed a "framed and battened door." The stiles and top rail should be of the full thickness of the door, whilst the middle and bottom rails and the braces are of the thickness of the door, less the battens. In a 2-in. door, the battens would be about $\frac{7}{8}$ in. thick, whilst the braces and middle and bottom rails would be $1\frac{1}{8}$ in. The middle and bottom rails are provided with bareface tenons, so that they may be brought as near to the centre of the thickness of the stiles as possible. The top rail and stiles are ploughed for the reception



Ledged and Braced. Doors. Framed and Braced.

of a tongue formed upon the top end of all the battens and the extreme edges of the two outer ones. The battens, besides being tongued to the outer framing, are nailed to the bottom and middle rails, and also to the braces, the nails being clinched as previously described. The braces are usually placed in such a position that their centres pass through the angles of the framing; by this precaution the thrust along their length is equally distributed to the framing.

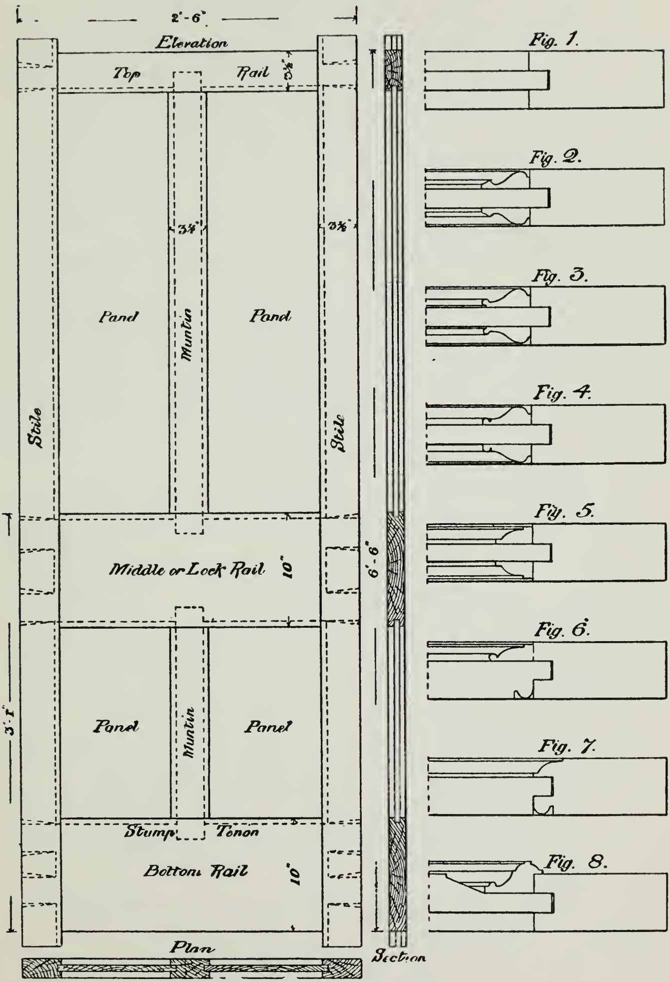
Braces.—These act as struts, and should incline upwards from the hanging to the closing stile. The extremities are sometimes plain-butted against the framing, and sometimes tongued; in the latter case they must be placed in position previous to wedging up.

Doors of this kind are usually used in external walls, and for warehouse and stable work. When used in positions where both surfaces are exposed to the wet, the top edge of the middle and bottom rails should be weathered (inclined outwards). The bottom rail should be kept about $1\frac{1}{2}$ in. or 2 in. from the lowest edge of the door; this is done for the purpose of keeping as much of the material as possible away from surfaces inclined to be damp. The exterior and interior elevation, also the vertical section of a framed and braced door, are shown on page 99.

A form of this door is used with church work of the mediaeval type, the battened portion passing over the whole of the framed portion, whilst upon the outside or battened surface mouldings are fixed to form panels.

Panelled Doors.—Of these there are several varieties, distinguished by the number of panels and by the finish given to them.

Interior doors are not required to be of such a large


2'-6"
Elevation
Top Rail
3⅞"
3⅞"
3⅞"
Panel
Muntin
Panel
Stile
Stile
Middle or Lock Rail
10"
6'-6"
Panel
Muntin
Panel
3'-1"
Stump Tenon
Bottom Rail
10"
Plan
Section
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.

size as those upon the exterior; the elevation given on page 101 is of standard size, being of a height of 6 ft. 6 in., and in width 2 ft. 6 in.; other sizes range upwards, increasing by inches in both dimensions, so that a door 6 ft. 9 in. high would be 2 ft. 9 in. wide, and one 7 ft. high would be 3 ft. wide.

The position of the middle rail is governed largely by aesthetic principles, but mainly for the purpose of fixing the lock. A convenient position for handling may be considered as 2 ft. 8 in. from the floor line; this may also be taken as the height of the centre of the middle rail. It has been recommended that the height of the top line of the middle rail should be at a distance of 3 ft. 1 in. from the floor line, but this rule alters the height of the centre of the middle rail as its width increases or diminishes.

The elevation given on page 101 is that of a four-panelled door, with the positions of tenons and panels dotted in. These have been arranged according to the instructions furnished in Chapter III. The different methods of finishing are shown at Figs. 1 to 8. Fig. 1 is a section through what is known as a square framed door with flat panels.

Fig. 2 represents a similar door, with drop or sunk mouldings of the quirked and filleted ogee type.

Fig. 3 is a similar section, having a beaded and quirked ogee moulding, another form of which is shown in Fig. 4.

The section shown at Fig. 5 has a filleted ovolo moulding.

Fig. 6 shows a section through the stile of a square framed door, with flat panel and sunk moulding on one side, and flush panel on the other.

In the section at Fig. 7 both moulding and bead have been worked upon the framing, the external appearance being somewhat similar to the above.

Fig. 8 is a section through the stile of a square framed door, with flat panel on one side, and a raised or "fielded" panel upon the other, the latter being provided with bolection mouldings. Mouldings projecting beyond the face of the work, and being rebated over the framing, are termed "bolection mouldings." An elevation of two raised or fielded panels provided with bolection moulding is shown on page 107.

Frieze Rails.—These pass across the door between the middle and top rail, as shown at Fig. 86. The panels above the frieze rail are known as "frieze panels."

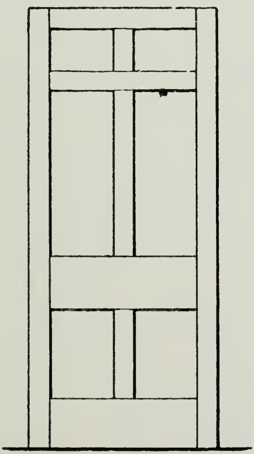


Fig. 86.

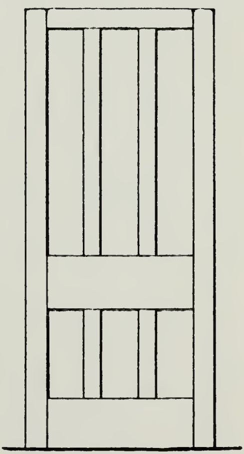


Fig. 87.

The width of muntins and frieze rails should not be so wide as the stiles by $\frac{1}{2}$ in., this portion being

hidden upon one side by the rebate of the linings. Sometimes the muntins do not pass beyond the frieze rail, and a long frieze panel is then necessary. This is the method usually adopted in the formation of a five-panelled door. Six-panelled doors are sometimes arranged, as at Fig. 87, with two muntins passing up through the door. The advantage of this arrangement with wide doors being that 11 in. stuff, or less, may be used without the necessity of jointing up, and the panels being of less width, the shrinkage is not so great. Folding doors are those which are hung in pairs, one from each jamb, as shown in elevation at Fig. 88. They may be made to swing or to close into rebates.

When doors are required exceptionally wide as compared with the height, and where they would otherwise appear unsightly, they are made to appear as in Fig. 88, but in reality they would open as one. These are termed "double-margin" doors, and are constructed as follows: The two halves are framed separately, but, previous to wedging up, the two inner stiles are fitted with three pairs of dry hard-wood folding wedges. The top pair should pass through the stiles about 3 in. below the top rail, as shown at *A* (Fig. 89). The other two pairs pass through the stiles 3 in. above the bottom and middle rails respectively. The rails of the two doors are first glued and wedged to the inner stiles, which have previously been prepared to the section shown in the figure, and properly jointed. The two inner stiles are then glued and wedged together, the ends of the latter having been cut clear of the plough groves, the panels are inserted, and the process of wedging up is then proceeded with in the ordinary

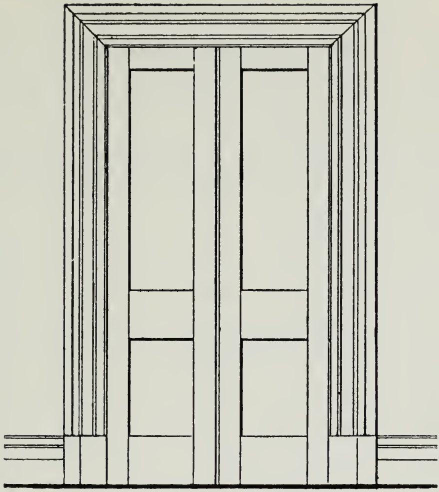


Fig. 88.

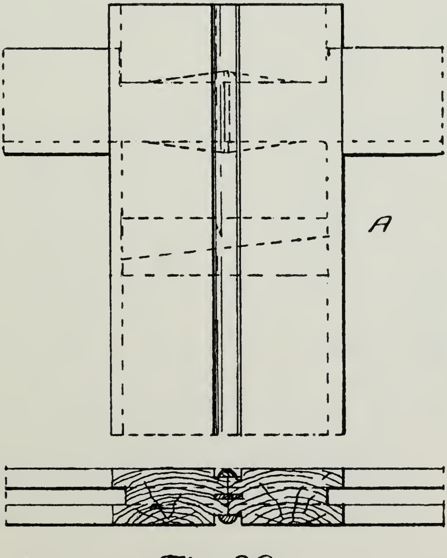


Fig. 89.

manner. The joint between the two halves is provided with a double-quirked bead, either worked upon the edges of the stiles, or planted on separately, as shown in section at Fig. 89.

Sash Doors.—Page 107 contains an elevation, with vertical and horizontal sections of what is known as a "gun-stock sash door."

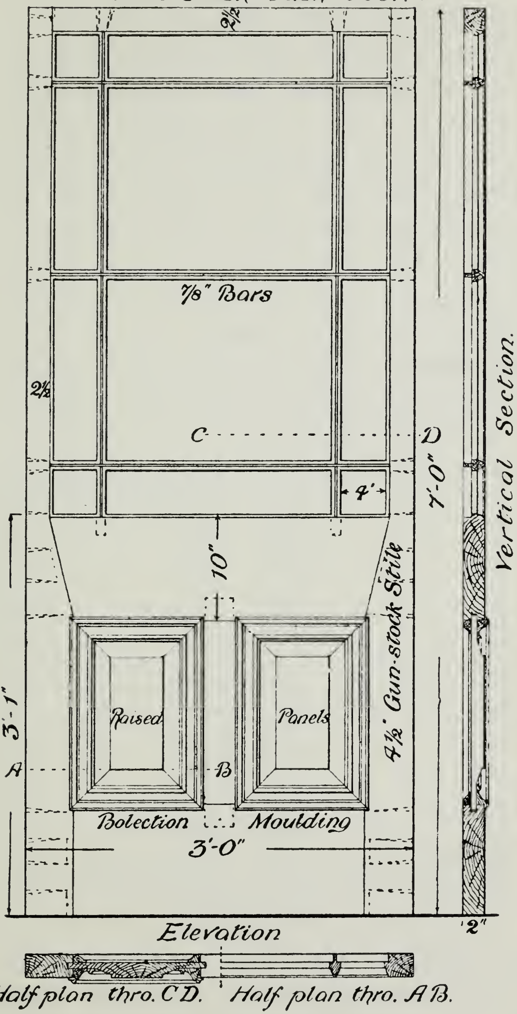
When doors, besides being used for ordinary purposes, are constructed with glazed panels for the purpose of admitting light, they are said to answer the double purpose of a sash and door, and are therefore termed "sash doors" or "glass doors." Sometimes the glass extends from top to bottom rail, as is the case with doors for shop fronts, in which case they are known as "all-glass doors."

Diminished Stiles.—Doors which have the upper panels glazed should be constructed with diminished stiles,—stiles tapering off to a narrow width as they approach the glazed portion,—so that they may permit so much light to pass as is possible.

Mitred Stiles.—When the diminution takes the form of a mitre line of 45°, passing from the lower corner of the middle rail back to a point in direct line with the diminished portion, and takes up a square shoulder line at this point, it is known as a "mitred stile."

Gun-stock Stiles.—When, as in Fig. 82, Chapter III., the shoulder line passes direct but obliquely across the rail, and when the shoulder of the stile is made to correspond with this line, it is known as a "gun-stock stile," and the shoulder as a "gun-stock shoulder." Gun-stock sash doors are those provided with the gun-stock stiles described above.

Gun-stock Sash-door.



Elevation

Half plan thro. C D. Half plan thro. A B.

Panels.—These may be finished in a variety of forms. A flat panel, strictly speaking, is one that has its surfaces perfectly plain and of such a thickness that it may be entered into its groove without rebating. These are illustrated in part section by Figs. 1 to 5 inclusive on p. 101. A flush panel is one that has its surface or surfaces finishing flush or level with that of the framing, and may be so upon one or both sides. Panels flush upon one surface only are known as "flush one side." A tongue is formed upon their edges by rebating, the joint between it and the framing being usually provided with a bead.

Bead Butt.—Flush panels having their vertical edges only provided with a bead are known as "bead butt" or "bead and butt."

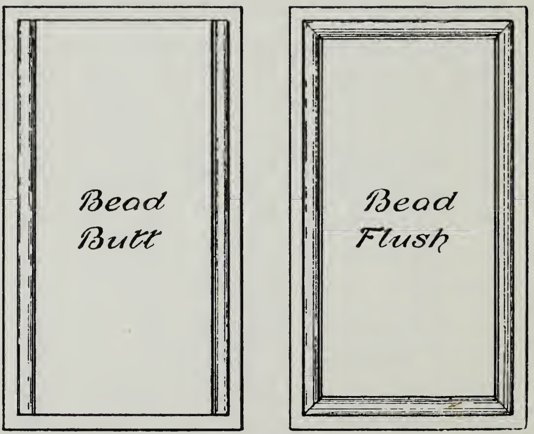


Fig. 89 a.

Bead Flush.—When the bead passes around the four edges of the panel, it is known as "bead flush." In place of working the end bead in the solid, a small portion of the material is cut away, and a special

worked bead glued and braded in its place. This method is objectionable, as the panel is not free to shrink and expand with the changes of the atmosphere, and often splits in shrinking. A better method is to work the bead upon the framing as shown in the section of Fig. 7, page 101.

Battened Panels.—Panels which are made up of a series of battens, with matched joints, are known as battened panels; they are often arranged so that the battens are placed diagonally, and, in this way, may act as braces or struts.

Raised or Fielded Panels.—These are panels which have had their margins recessed, the recessing usually being inclined to the surface. Elevations and sections of these are shown on page 107.

Draped Panels.—These are panels which have been moulded upon their surface to imitate the folds of linen, the ends being returned to match. They are sometimes termed "linen panels."

Jib Doors.—Doors leading to private apartments, and not intended to be conspicuous, are sometimes constructed in walls. They are usually flush with, and take up, the line and character of the surrounding work, and are termed "jib doors."

In some of the best classes of work, doors are finished with different woods upon their surfaces. They are usually constructed in halves, each side being of the same material as the work surrounding it. They are fastened together by means of dovetail keys driven through the inner surface of the stiles; the joints at the edges of the door are then covered with a veneer of like material.

Frames.—In buildings of the warehouse type, or

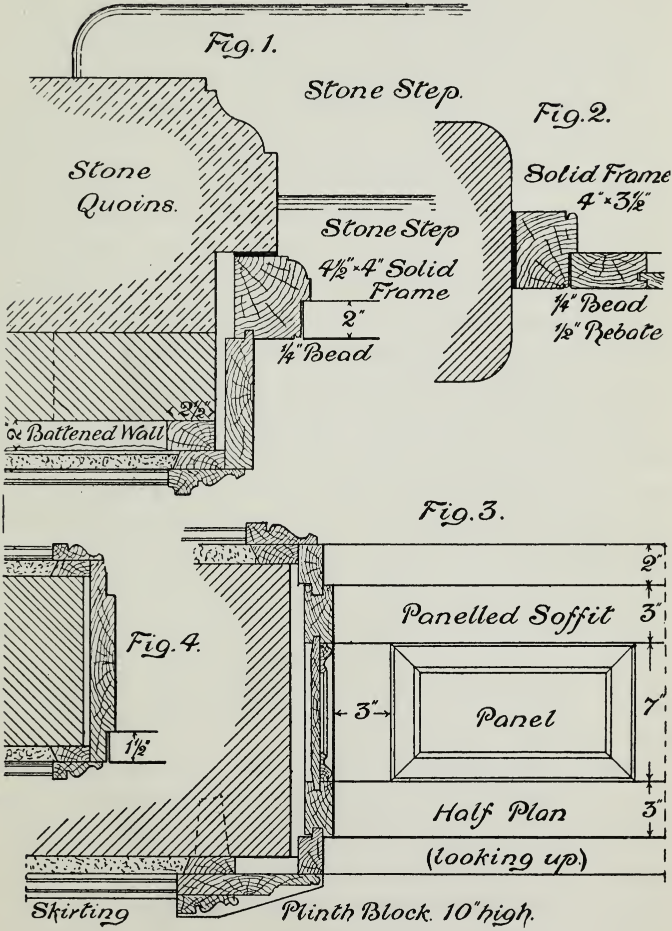
where the walls are left bare, doors are hung to solid frames, fixed upon the surface of the wall or in rebates. External doors are also hung to solid frames. In interiors of buildings of the dwelling-house type, linings, panelled or plain, are fixed around the doorways, and the doors hung to these.

Solid Frames.—Fig. 1, page 111, is a section through one jamb of a solid door frame fixed to a stone wall, battened upon the interior. The $4\frac{1}{2}$ in. by 4 in. solid frame is moulded with an ovolo upon its front edge, the rebated joint between the door and frame being beaded. The frame is made fast to the quoins by boring, plugging, and screwing; the heads of the screws are sunk below the surface, and the holes plugged. The jambs upon the interior are furnished with plain linings, and finished with a band moulding.

Fig. 2 is a section through one jamb of a solid frame fixed in a doorway, the brickwork of which is left bare. If the door frame is fixed as the wall is being built, the head may be left long to the extent of 3 in. or 4 in., and built into the wall. This method is usually adopted in doorways having segmental arches and, consequently, no lintels, the head of the frame being made to "take up" the line of the arch.

Jamb Linings serve the double purpose of covering or lining the edges of walls at openings, and providing a framework of wood from which to hang the door. Rebates are provided at both edges, although it is seldom that both are used. They are in width (rebates included) equal to the thickness of the wall they cover plus the rendering on both sides, and are fixed to "grounds" or blocking at the back. A set of linings

Solid Frames & Jamb Linings.



consists of two jambs or vertical pieces and one head or soffit.

Plain Linings.—In some cases the linings are so narrow that they will not allow of being panelled; they are consequently left plain, as shown in Fig. 4, page 111, and the rebates worked on the solid.

Panelled Jamb Linings.—Fig. 3, page 111, is a section through one jamb of a set of panelled linings, with a half-plan of the soffit, looking up. The framing is taken at 3 in. wide, and the rebates are tongued on. This latter process is recommended as giving the opportunity of covering the ends of the tenons and providing a more substantial edge for hanging purposes. Splayed grounds are provided upon either side, and the joints between the plaster and grounds covered by band mouldings or architraves.

The term "architrave" was originally applied of the lowest member or division of an entablature, and which rests immediately upon the capital of a column, and is now applied generally to the moulded margin around the front edges of linings to doors or window openings. It is not recommended to carry the delicate members of the architraves to the floor level, but to stop them at about 10 in. or 12 in. above, and finish upon a plinth block, as shown at Fig. 88, and in plan at Fig. 3, page 111.

Band Mouldings.—When the moulded margin around a door or window opening assumes the less dignified form shown in the upper portion of Fig. 3, page 111, it is known as a "band moulding," another section of which is shown at Fig. 1 upon the same page.

Double-faced Architrave.—When an architrave

presents two plain surfaces, it is known as "double-faced." The architrave shown in section at the lower portion of Fig. 3, page 111, is known as double-faced.

Grounds.—The wood foundations upon which architraves and band-mouldings are fixed are termed grounds. Their backs are grooved, rebated, or splayed for the purpose of forming a key for the plaster, and are fixed by means of plugs, wood pallets or joints, and wood bricks, and, in addition, they are sometimes framed from back to front by rails dovetailed between them. When mortised and tenoned together, they are known as "framed grounds."

Plugs are small pieces of tapered wood driven into a wall after it has been built; they should be cut winding, so that they may have an opportunity of holding to the wall, even after shrinking.

Pallets or Wood Joints.—These are of the same length and width as a brick (9 in. by $4\frac{1}{2}$ in.), and of a thickness equal to the mortar joints (about $\frac{1}{4}$ in.). They are built in with the work as it proceeds, at distances of about 18 in. from each other. These are found to be by far the best means of fastening, as, being thin, the liability to shrinkage is reduced, whilst there is no necessity of raking out the joints of brickwork so soon after being built.

Wood Bricks are sometimes used for fixing, but they are liable in dry walls to shrink away and become loose, whilst in wet walls they are liable to rot.

Fixing Blocks.—These are made of a composition of coke-breeze and cement. They are of such a nature that a nail may be driven into them, and at the same time they are not subject, as is the case with wood, to dry rot.

CHAPTER VII.

SASHES AND SASH FRAMES, LANTERN LIGHTS, SKYLIGHTS, Etc.

The construction of sashes, sash frames, and skylights forms another important section of the work that may be said to come strictly under the category of joiners' work. Perhaps the most useful and convenient may be considered as being the sliding sashes in cased frames.

Figs. 1, 2, and 3, page 115, represent the interior elevation, with vertical and horizontal sections respectively of a pair of vertical sliding sashes, with cased frame, and sometimes known as "double-hung sashes with cased frame." With the half plan or horizontal section, is shown a half plan looking down upon the top of the head. Although it is not usual in practice to show this, it has been done here to illustrate the method of blocking the head of the sash. It will be seen on looking at the sections that the casing is simply nailed together without tongueing, this being the method adopted in the commonest class of work. The following is a brief description of the various parts :

Sill.—This is the lowest member of the framing ; it

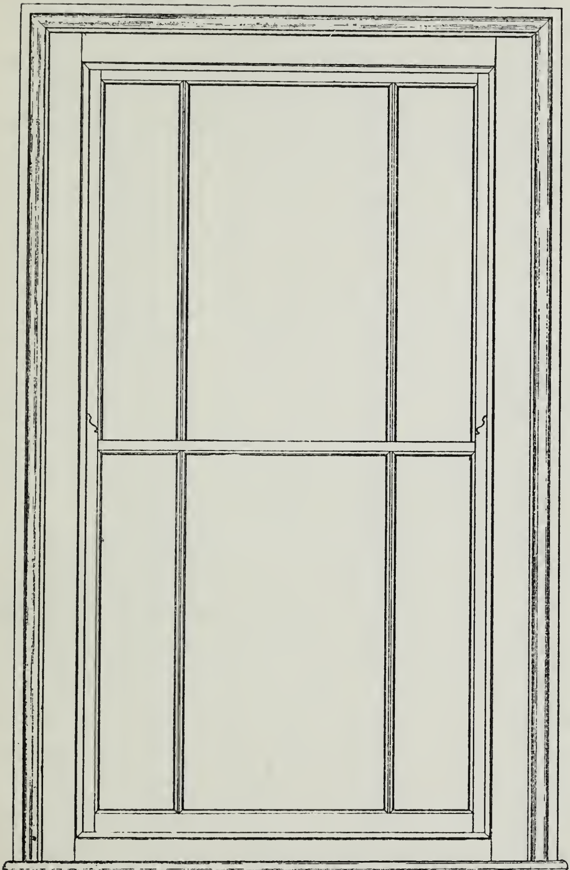


Fig. 1.

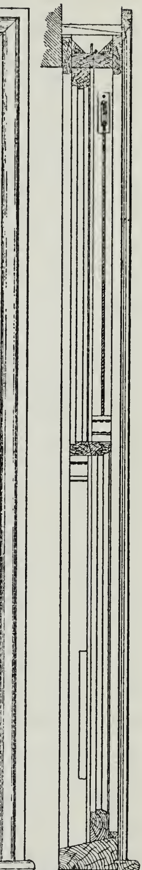


Fig. 2.

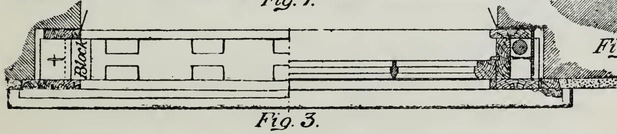


Fig. 3.

should at least have its top surface weathered, so that the water may not lodge upon it; but it is far better to have at least one sinkage upon its surface, and if this is throated the water will be prevented from being driven back to the interior. Fig. 3, page 117, represents a part section through such a sill provided with a ventilating bead. The section has been taken with the sash lifted to a height equal to the thickness of the meeting rail. This allows a current of air to enter the room through the open joint between the meeting rails. The splayed joint of the meeting rails acts as a baffler, sending the fresh air back to the glass, and dispersing it about the room without creating direct currents of cold air. It is found to act in every way satisfactorily. Sills should be constructed of hard and durable wood, such as oak or teak, as they are fixed in positions which render them liable to dry rot.

Pulley Stiles.—These are the vertical side pieces against which the sashes slide, the parting bead being tongued along the centre. Pulley stiles are fixed by being sunk into the sill to the extent of about half the thickness of the latter; they are also wedged and spiked (nailed). It is most important that the pulley stile shall be faced up perfectly true, or the casing when fixed will take up the irregularities. Pulley stiles may be either plain or tongued at the edges; in exposed situations it is necessary to have them tongued. They are usually constructed in fir, but in the better class of work, mahogany or teak is used.

Pulley Heads.—These connect the tops of the pulley stiles, and are either housed or tongued, and grooved at the joint. They are, with the exception of the centre groove, usually of the same section as the

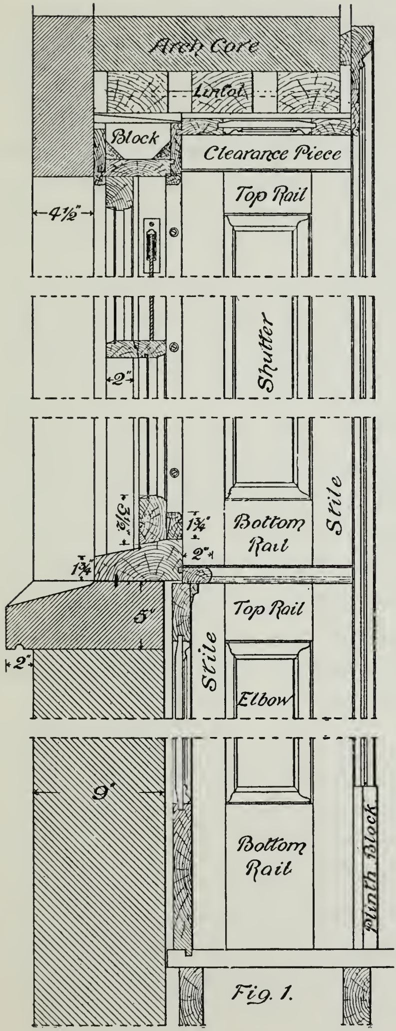


Fig. 1.

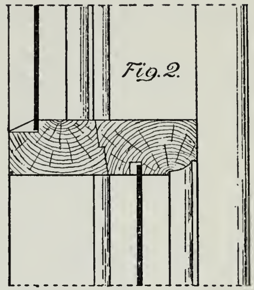


Fig. 2.

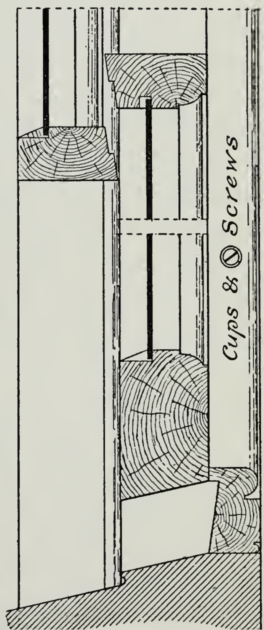


Fig. 3.

pulley stile; it is not usual to provide a parting bead at the head except in exposed situations.

Inner Casings.—These are nailed to the inner edge of the pulley stile, to the sill and head, and in the better class of work are of the same material as the interior fittings of the compartment, and are of a thickness ranging from $\frac{3}{4}$ in. in common work to 1 in. in the better class, and of a width varying with the surrounding circumstances.

Outer Casings.—These are the casings which are fixed to the outside edge of the pulley stile, the extreme edge projecting to the extent of $\frac{5}{8}$ in. or $\frac{3}{4}$ in. beyond the face of the pulley stile.

Parting Beads.—These are beads fixed to the centre of the pulley stiles, and which form the partitions between the channels in which the sashes slide. They are usually of the same material as the pulley stiles, are $\frac{3}{8}$ in. in thickness, and should project beyond the face of the pulley stile to the same extent as the outer casing. They are tightly fitted to the groove of the pulley stile, and by this means only should they be held in position.

Stop Beads.—These are the movable beads, nailed or screwed to the edge of the inner casings. They should be of such a thickness that the inner surface is in direct line with the crown of the parting bead and the edge of the outer casing. They are sometimes of such a width that they pass over the joint between the casing and pulley stile, and in the better class of work are sometimes fixed in rebates by means of brass "cups and screws."

Parting Laths or Slips.—These are contained inside the casing, and are hung loosely from the centre

of the ends of the pulley stiles; they prevent the weights from striking each other. In ordinary work they are of fir, and about $\frac{1}{4}$ in. thick; but in the best work they are often of stout zinc.

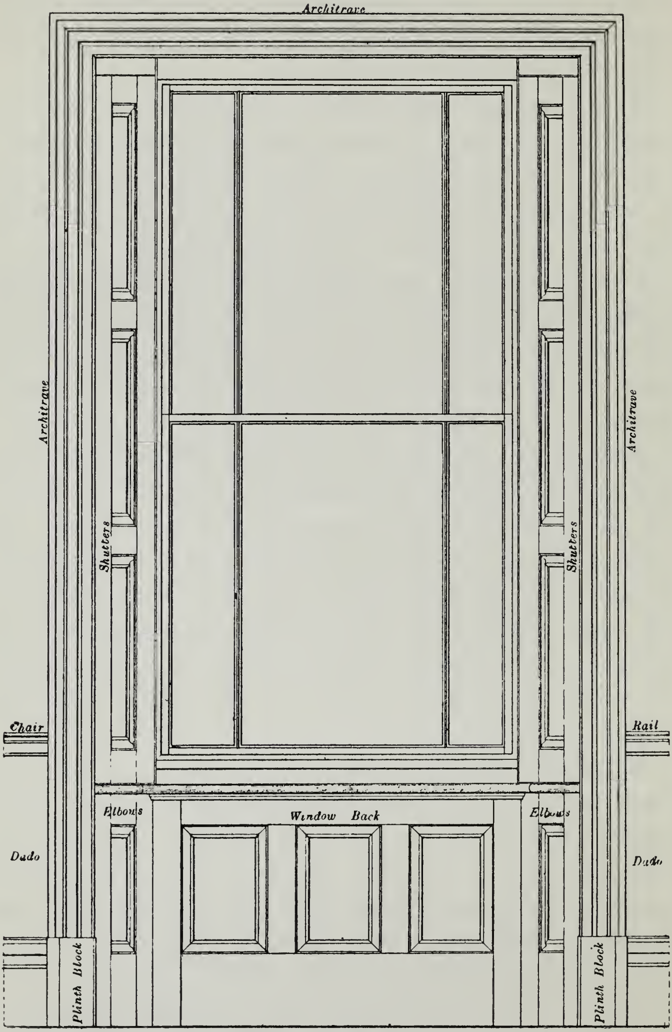
Back Linings.—These are usually of $\frac{3}{8}$ in. material, tongued to the inner casing, and nailed upon the back edge of the outer casing. They complete the boxing of the weights, and prevent the latter being caught upon the rough surface of the brick rebates.

The sashes slide in vertical grooves formed by the casing, and are balanced by lead or cast-iron weights attached to cords passing over pulleys, the latter being fixed about 3 in. from the top of the pulley stiles.

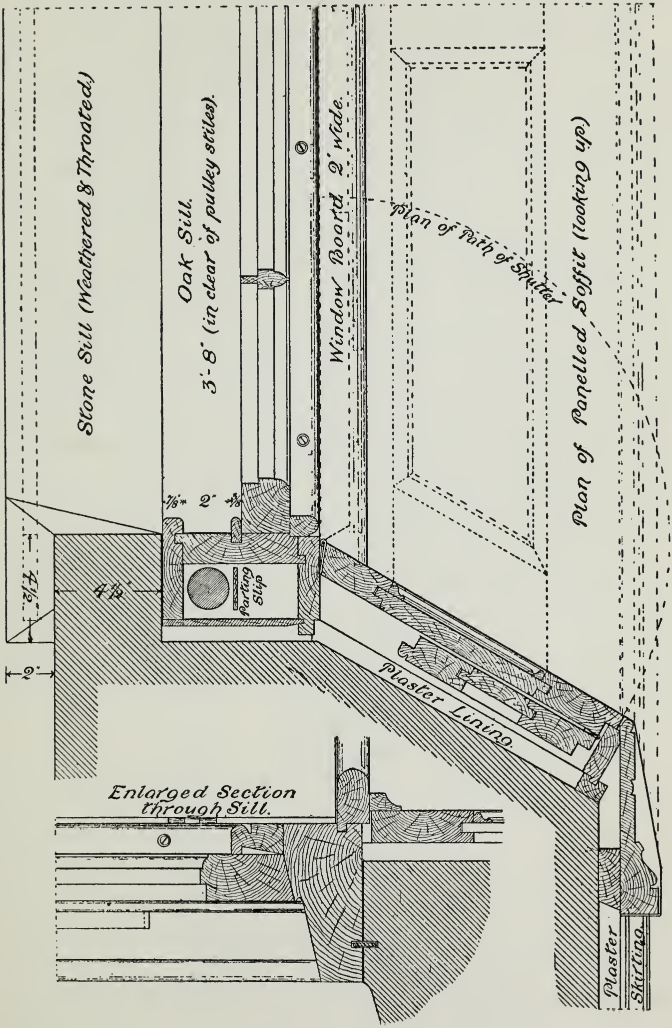
Brackets.—The joints between the meeting rails and stiles of sashes are sometimes dovetailed, but if the ends of the stiles were allowed to project, the ordinary form of tenon would suffice, and is calculated to make the stronger joint; the ends of the stiles in this case should then be moulded in the form of a bracket. This method is shown on p. 115, Figs. 1 and 2, and in practice is found to cause wide sashes to "run" freely.

Window Boards.—Narrow "boards" or battens, sometimes only $1\frac{1}{2}$ in. wide, are tongued to the inner surface of the sill, to create a finish and "break" the joint between it and the plaster below. They have their front edges moulded (usually a half-round) and the ends "returned," and are convenient for butting the ends of the band moulding upon.

Page 120 contains an interior elevation of a pair of 2 in. double hung sashes and cased frame, fixed in a two-and-half brick wall, with splayed boxed shutters



INTERIOR ELEVATION


Stone Sill (Weathered & Throated.)
Oak Sill.
3'-8" (in clear of pulley stiles).
Window Board 2' wide.
Plan of Path of Shutter
Plan of Panelled Soffit (looking up)
Parting Slip
Plaster Lining.
Enlarged Section through Sill.
Plaster
Skirting
2"
4½
2"

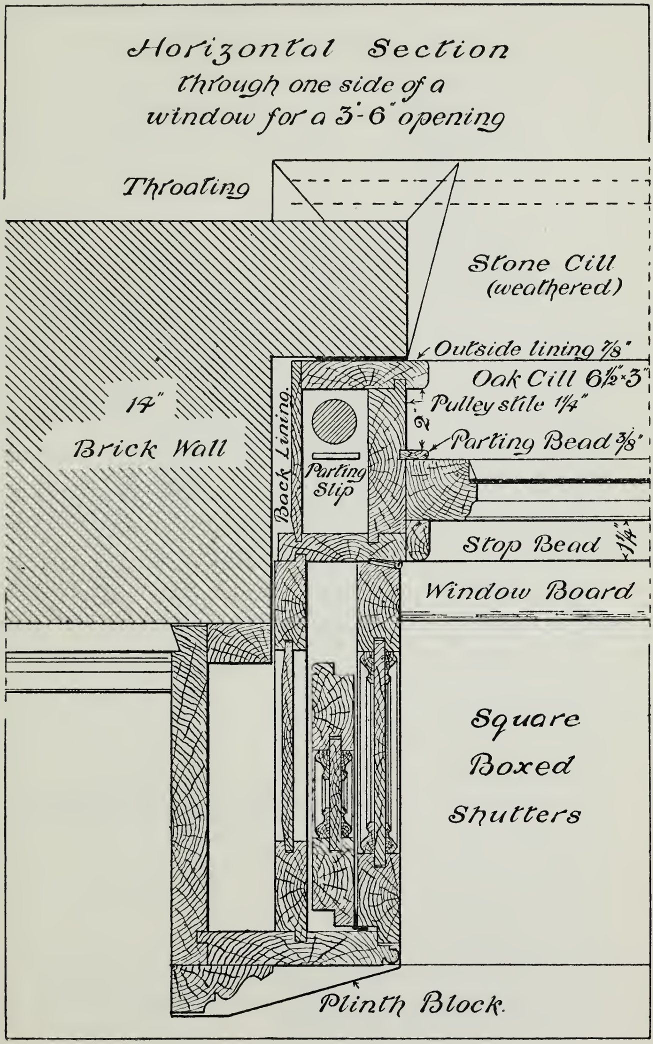
and with window back and elbows complete, enlarged details of which will be seen on pp. 117 and 121.

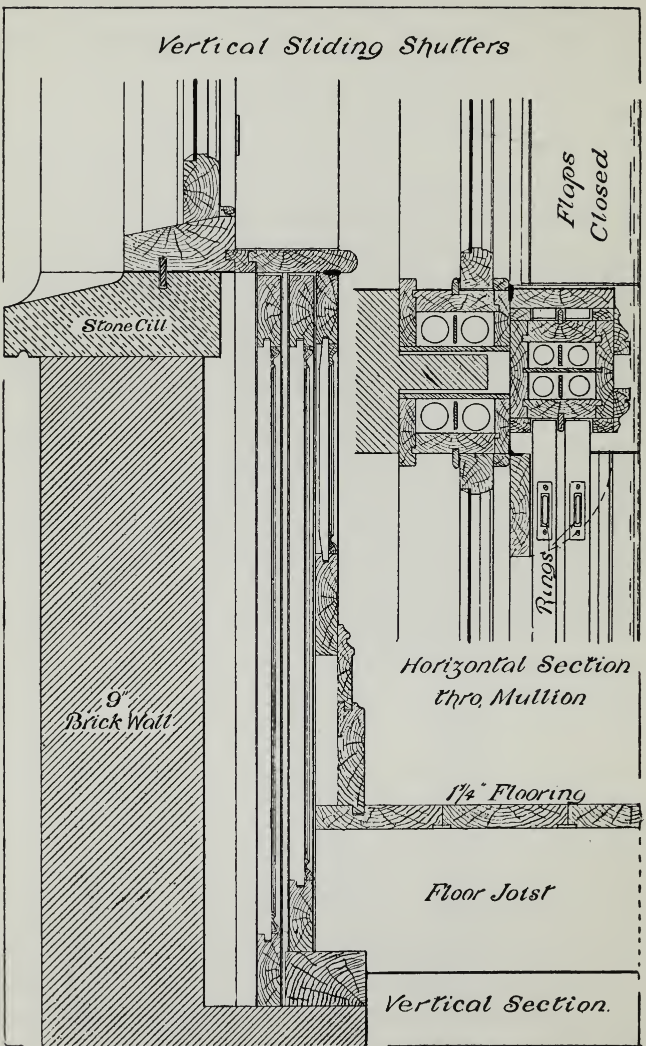
Boxed Shutters.—These are shutters which fold back in "leaves" into boxings as shown on pp. 117, 120, 121, and 123. Page 121 contains an example of splayed boxed shutters in a $22\frac{1}{2}$ in. brick wall. The wall, in this case, being thick enough to receive the whole of the shutters without the necessity of the boxing standing out into the room.

Square Boxed Shutters are those which stand out at right angles to the wall. In thick walls, they may be arranged within its thickness; but when, as in the section on p. 123, the wall is thin, the boxings may stand out into the room. Advantage may be taken in such an arrangement to create a window seat; whilst the only objection is that the boxing is apt to block the light from parts of the room.

This latter objection may be obviated by allowing the shutters to close back in narrow recesses against the face of the wall. The first panelled leaf is then provided with a plain return piece, wide enough to allow the shutter to close back into its boxing and having at the angle a rule joint.

Vertical Sliding Shutters.—Another method of disposing of shutters, especially where the wall is not a thick one, is to slide them vertically downwards behind the window breast; a vertical and horizontal section is shown on p. 124. They are balanced in the same manner as sliding sashes, casings being required as for the latter. The window board is here made to answer the purpose of a cover or flap which, when open, reveals the shutters. Similar flaps may be provided to close against the vertical portion of the casing.


Horizontal Section
through one side of a
window for a 3'-6" opening
Throating
Stone Cill
(weathered)
Outside lining 7/8"
Oak Cill 6½"×3"
Pulley stile 1¼"
2"
Parting Bead 3/8"
14"
Brick Wall
Back Lining.
Parting
Slip
Stop Bead
1¼"
Window Board
Square
Boxed
Shutters
Plinth Block.

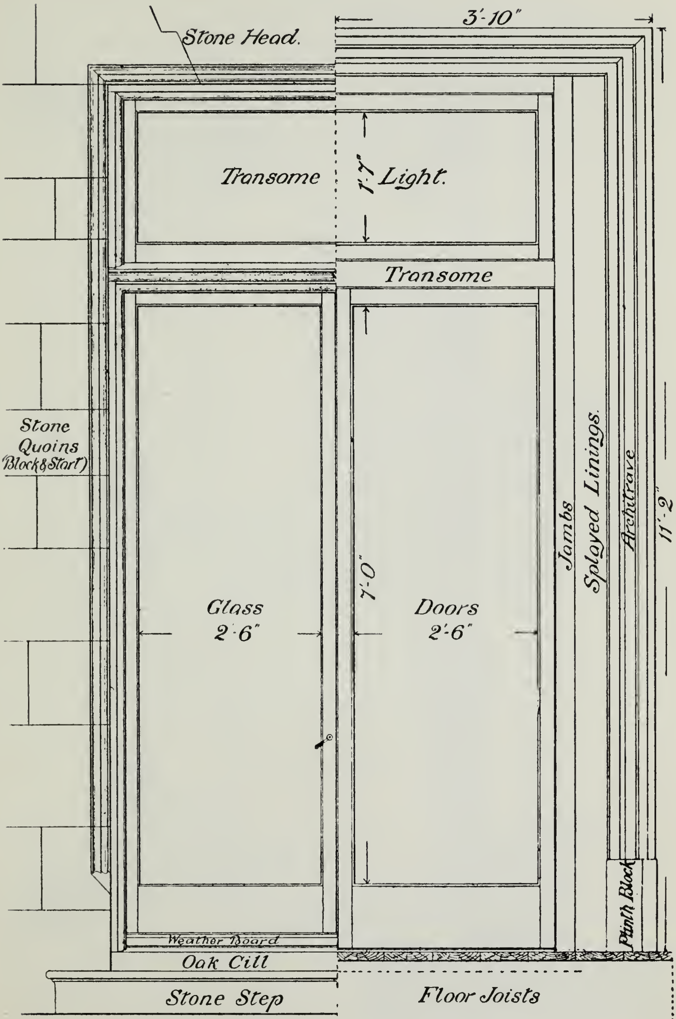

Vertical Sliding Shutters
Flaps Closed
Stone Cill
Rings
Horizontal Section thro. Mullion
9" Brick Wall
1¼" Flooring
Floor Joist
Vertical Section.

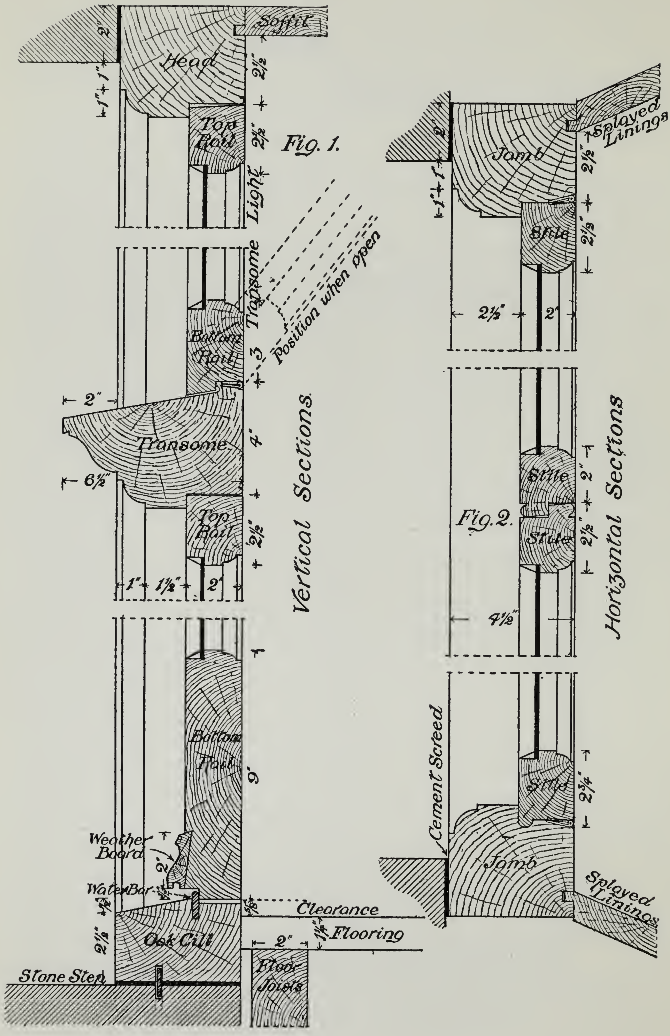
Advantage is taken of the depth behind the joist and wall plate to allow the shutters to pass down behind them. The shutters are usually made for this purpose in two leaves, and, in the case of lofty windows, require even more depth than has already been suggested; for this purpose the brickwork may be recessed to the extent of two or three courses behind the wall plate. Rings are provided in the top edge of the shutters for lifting purposes, and are so constructed that, when not in use, they fall below the surface of the top plate.

French Casements.—This is another form of sash door, but in this case the sash, which was primarily constructed for the purpose of light, has been made to take the form of a door for the convenient approach to a veranda or balcony. Page 127 contains half elevations of such a casement; that to the left of the centre line represents a half elevation of the exterior, whilst on the right is shown a half elevation of the interior. The stiles, in this case, are made so frail that it is not advisable to sink the lock below its surface. For this reason, special locks and bolts are provided; the latter are known as espagnolette bolts; they are screwed upon the surface of the stile, and are constructed in such a manner that by turning a small handle, placed in a convenient position along it, the lengthened bolt engages with the sockets both at the top and bottom. Sections of the above casement are given on page 128. Sashes of this kind are made to open outwards as well as inwards, special advantages being claimed for each. In exposed situations, it is suggested that the best results are obtained by hanging the doors to open towards the outside, as when the force of the wind presses against them, they are closed into the rebates.

When hung in this manner, and left open, they are liable to be caught by the wind, and great care has to be exercised to fasten the door when open, so that it may not slam. When the doors open towards the interior there is a difficulty in closing the joint at the sill. In order to overcome this difficulty several patent water-bars have been introduced with greater or less success. The section given on page 128 has been provided with an ordinary wrought-iron tongue against which the door closes, whilst a projecting weather-board has been fixed upon the outer edge. The frame has here been provided with a transome and transome-light for ventilating purposes. As will be seen from the section, the light has been hung from the transome; this arrangement prevents down draughts, and disperses the air along the ceiling, where it mixes with and dilutes the vitiated atmosphere of the interior, purifying it, and rendering it less objectionable. In the horizontal section two methods of closing the joint at the stile are shown; the lower one is considered to render the joint more secure in exposed situations.

The frames for French casements are always solid, but may be constructed with or without the transome rail shown on page 127. Casement sashes with solid frames are sometimes used in work known as "Elizabethan"; they are somewhat similar in detail to the French casement, but are not used as doors. They are sometimes constructed in sets with solid mullions dividing them into double, treble, or quadruple lights, and are known as two-light or three-light casements, according to the number of divisions contained by the frame. These are also constructed with or without


3'-10"
Stone Head.
Transome Light.
1'-7"
Transome
Stone
Quoins
(Block & Start)
Jambs
Splayed Linings.
Architrave
11'-2"
7'-0"
Glass
2'-6"
Doors
2'-6"
Plinth Block
Weather Board
Oak Cill
Stone Step
Floor Joists


Soffit
Head
Top Rail
Fig. 1.
Light
Transome
Position when open
Bottom Rail
Transome
Top Rail
Vertical Sections
Bottom Rail
Weather Board
Water Bar
Clearance
Flooring
Oak Cill
Stone Step
Floor Joists
Jamb
Splayed Linings
Stile
Fig. 2.
Stile
Stile
Horizontal Sections
Cement Screed
Stile
Jamb
Splayed Linings

the horizontal member known as the transome. All top surfaces of the framing exposed to the rain should be weathered so that the water may easily run off. It is advisable to throat them also, so that the water may not be driven back. Fig. 90 is a section of a wood sill weathered and throated.

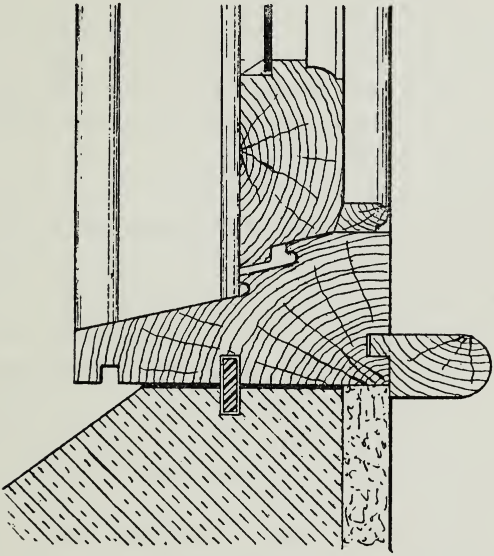


Fig 90

Capillary Attraction.—When two surfaces are placed so that only a small space exists between them, and when placed with their lower edges in contact with water, the latter will rise vertically to a considerable extent above the normal surface of the liquid, not by absorption alone, but by capillary attraction, and the height to which the water may rise increases as the space diminishes.

Throating.—Water has also the power of adhering to the under side of horizontal surfaces, and, if allowed to do so, will travel some distance in this manner, and often find its way to interiors. To avoid this, grooves wide enough to prevent capillary attraction are sunk into the under surface of projecting wood-work; this is termed "throating." Another form of throating is adopted on the vertical edges of sinkages on wood sills, to prevent the wind from driving the water from the lower to the higher surfaces; the force of the wind is checked by the throating, and the water thrown back upon the lower surface.

It will be seen from Fig. 90 that all these points have been considered in the design of the joint; not only that, but the joint between the bead of the sill and the bottom rail has been prepared in a manner somewhat similar to that of the meeting rails. It requires but little additional labour in its preparation, and is the means, in exposed situations, of keeping out all cold currents of air. The sash, as it is lifted, at once clears itself, and no loose joint or other clearance is required.

The approximate area of window surface for the lighting of a room may be found by extracting the square root of the number of cubic feet obtained by multiplying together the length, breadth, and height as follows:

$$\text{Area in sq. ft.} = \sqrt{\text{Length} \times \text{Breadth} \times \text{Height}}.$$

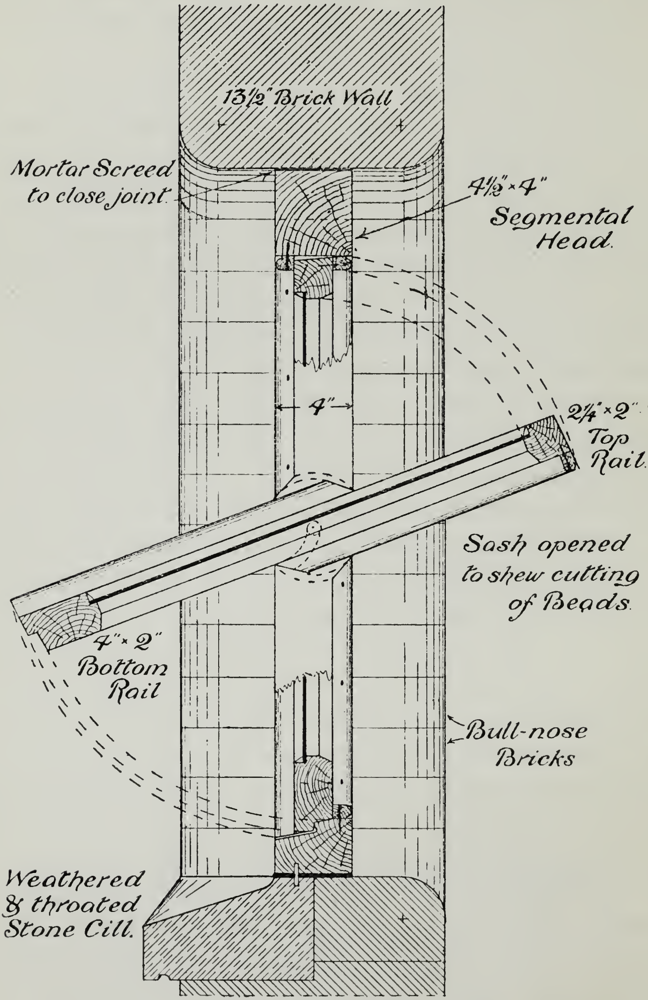
Borrowed Lights.—These are small sashes placed in partitions for the purpose of giving light to inner rooms or staircases not sufficiently lighted from other sources. They are fixed in framing, formed of a set of

linings, with window-board, the latter usually extending beyond the surface of the wall, and having its edges rounded. The linings are provided with band moulding, mitred at the top angles, and butting upon the window-board at the bottom.

Horizontal sliding sashes are sometimes used in outhouses; they are more difficult to construct than ordinary hinged casements, and do not give good results. They are peculiar to some localities, and when one sash (the outside) is constructed with the frame, the other sliding upon a tongue or in rebates, they are known as "Yorkshire lights." The closing joint is provided with beads projecting from the face of the sashes and forming rebates.

Pivoted Sashes.—This form of sash is shown on page 132; they are used principally in buildings of the warehouse class, and in stables, and the method is often adopted for the opening of the ventilating sashes in lantern lights. The advantage gained in the latter position is obvious from the fact that the sash, always balanced upon the centre pin, requires little power to open it. The position to which the sash may be opened may vary from the horizontal to the position indicated in the illustration. Some architects prefer the former, whilst others are of the opinion that the sash should incline as indicated. The position of the centre pin should be a little above the centre of gravity, so that the preponderance is always in favour of the closing of the sash. A good rule to adopt is to place the pivot in the centre of the clear line midway between the "squares." It will be seen that certain parts of the beads are fixed to the frame, whilst the others are fixed to the sash. The exact position of the

Pivoted Sash and Solid Frame.



joint may be determined by placing lines across the side of the frame in the direction and position occupied by the crowns of the beads when the sash is open. These lines will mark the extreme points of the joints, and, if from the centre of the position of the pivot, a circle be drawn, having for its radius the distance between this point and the extreme points alluded to above, then tangents to this circle will represent the line of junction between the beads. The "centres" for the above are sold in pairs, one having a pivot upon the plate, whilst the other has a corresponding socket grooved from the side for the convenience of hanging.

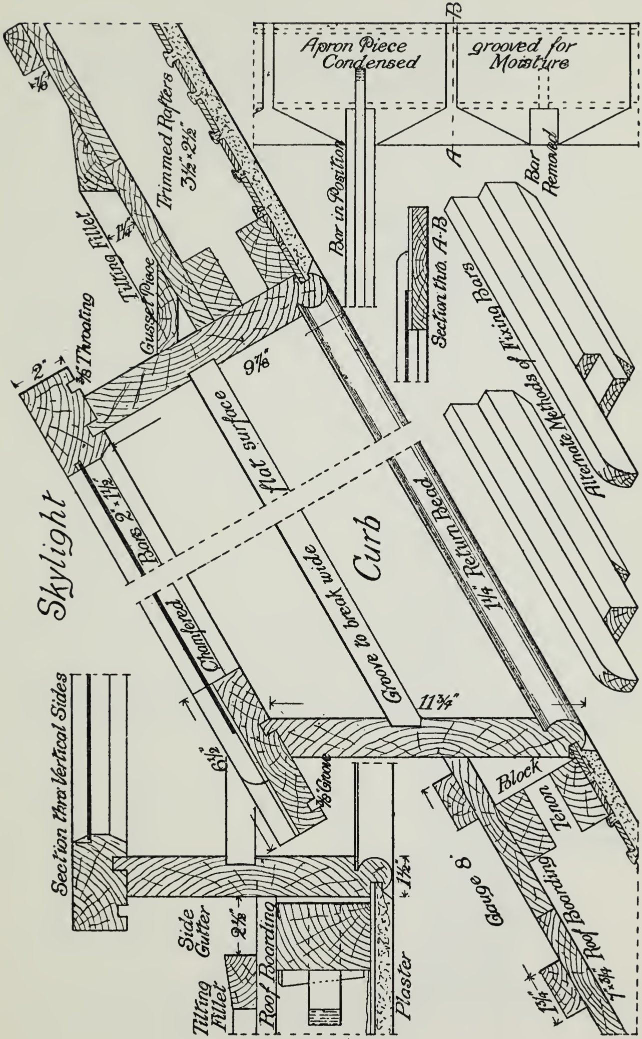
The pivot may be attached to the sash, and the socket to the frame; in this case the groove of the socket has to be carried to the edge of the frame. This method has the objection that the end of the groove, appearing upon the surface, is unsightly. To avoid this, the pin may be attached to the frame, and the socket to the sash; in this case the groove is carried to the splayed butt-end of the bead, and, in that position, is not so conspicuous. Allowance must, in this case, be made in the joint of the outer bead by raising the joint to the extent of half the thickness of the sash, so that the sash may be passed into its position.

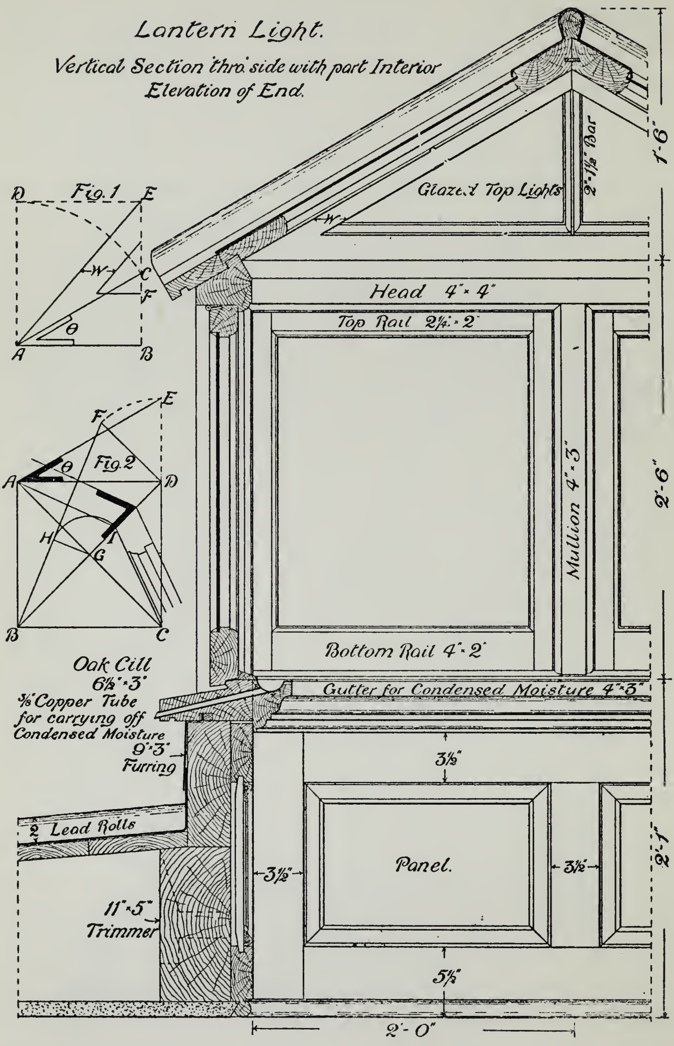
Dormer Lights.—These are windows constructed in the sloping surfaces of roofs. They are distinguished from skylights by standing vertically, whilst the latter lie in a surface parallel to the plane of the roof. They are often constructed as casements, but may be of any of the forms previously described.

Skylights.—These are sashes of a peculiar construction lying in the plane, or parallel to the surface

of the roof. They are fixed to, or hung from, the upper portion of a curb or lining. For the purpose of fixing skylights, the common rafters are cut and trimmed in a manner somewhat similar to the trimming of joists, and a curb or lining is fixed as shown on page 135. The bottom rail of a skylight is known as an apron piece, and is thinner than the light by the depth of the rebate and plus a small amount usually allowed for the escape of the moisture which condenses upon the cold surface of the glass; in some cases channels are cut in the top surface of the apron piece for the same purpose. Two methods are shown of the joint between the bars and apron piece, whilst the latter is joined to the stiles of the light by means of bareface tenons.

Lantern Lights.—These are glazed enclosures constructed at the ridges of sloping roofs or upon lead flats, for the purposes of light and ventilation to rooms or staircases below. They are a decided improvement upon skylights, but are more expensive to construct. The roofing timbers are trimmed around in the usual way, and curbs are made to stand at least 6 in. higher than the highest part of the roof adjoining. These are firmly secured at the angles, by dovetailing or other means equally secure, and with the trimmings cased by plain or match boarding or by panelling. Solid frames with projecting sills of hard wood rest on, and are secured to, the curbing, the whole being crowned with a lead flat or glazed top lights, as shown in the part section and elevation contained on page 136. Between the glazed side lights and the panelling or "combing," as it is sometimes called, a gutter should be fixed so that the condensed vapour may pass away to the


Skylight
Apron Piece Condensed
grooved for Moisture
A
B
Bar in Position
Bar Removed
Section thro. A-B
Alternate Methods of Fixing Bars
Trimmed Rafters 3½"×2½"
Tilting Fillet
1¼"
Gusset Piece
⅜" Throating
2"
⅞"
9⅞"
flat surface
Bars 2"×1½"
Chamfered
Groove to break wide
Curb
1¼" Return Bead
11¾"
6½"
⅜" Groove
Block
Tenon
Gauge 8"
1"×3¼" Roof Boarding
1¾"
Section thro. Vertical Sides
Side Gutter
2⅛"
1½"
Tilting Fillet
Roof Boarding
Plaster


Lantern Light.
Vertical Section 'thro' side with part Interior Elevation of End.
Fig. 1
D
E
W
C
F
θ
A
B
Fig. 2
F
E
A
θ
D
H
I
G
B
C
Glazed Top Lights
2"·1½" Bar
W
Head 4"×4"
Top Rail 2¼"×2"
Mullion 4"×3"
Bottom Rail 4"×2"
1'-6"
2'-6"
Oak Cill 6½"×3"
⅜" Copper Tube for carrying off Condensed Moisture
Gutter for Condensed Moisture 4"×3"
9"·3" Furring
2 Lead Rolls
3½"
Panel.
3½"
3½"
5½"
2'-1"
11"×5" Trimmer
2'-0"

exterior. The details of construction may best be seen on examination of section on page 136. The top lights are nere hipped; the horizontal width of the margin W is obtained by developing the angle, as seen at Fig. 1, page 136, θ being the angle of inclination of the top lights. Fig. 2, page 136, represents the method of obtaining the bevel of the joint at the hip, and which may be described as follows:—Draw the single lines ABC, representing the plan of the angle, with BD as the plan of the hip. Construct the angle EAD equal to the pitch of the top lights (θ). Draw FD equal to ED, and at right angles to DB. Join F with B. Draw AC at right angles to BD, and intersecting it in G. From G construct GH at right angles to FB, and intersecting it in point H. With G as centre, and GH as radius, construct the arc HI, intersecting BD in I. Join AI and IC. AIC is the angle between the planes of the top lights, and AIG its mitre. For the purpose of covering the angles, ridge rolls are required; these are shown in position upon the illustration, page 136.

CHAPTER VIII.

ROOFS.

In our consideration of roofs, attention will not be paid so much to the actual covering itself as to the means of its support. They vary in outline according to span, character of work it is intended to cover, and also to climatic conditions.

Pitch.—In some parts of the continent, where they are favoured with much sunshine and little rain, the tendency is to construct flat roofs with wide overhanging eaves, so as to produce as much shade as is possible; whilst towards the north, where heavy rains and snows prevail, the custom is to make the roofs steeply pitched. Again, the character of the building to be covered influences the pitch to a great extent. In classic buildings the roofs are usually pitched at about 25°, as were also those of the late Gothic, whilst those of the German renaissance and early Gothic were steeply pitched, even to the extent of about 60°. Page 140 contains a series of single line diagrams illustrating the method of treatment of spans from 8 ft. to 45 ft. and above.

Lean-to Roof.—This roof is intended for small outbuildings constructed against the walls of main buildings. Common rafters only are used in spans up

to 10 ft.; these are notched or birdsmouthed and spiked to the wall plates, and the roof covering attached. The stability of such a roof depends greatly upon the fixing at the tops of the rafters; unless thoroughly well supported here, the thrust along the rafters has a tendency to overturn the lower wall.

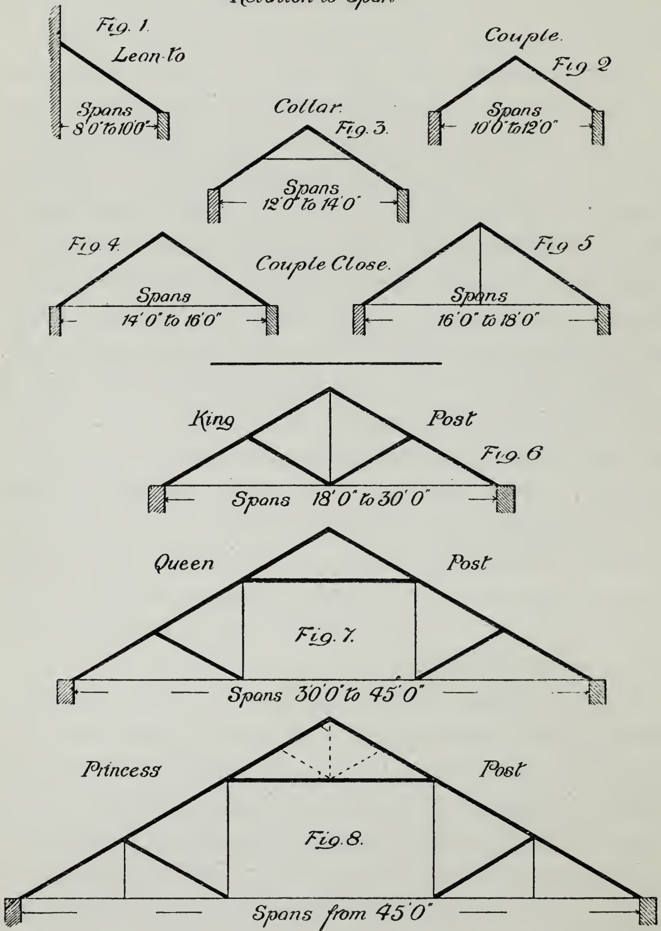
Couple Roofs.—In this case common rafters are used in pairs or couples, one from either wall. They are secured by spiking to the ridge piece, the lower ends being notched or birdsmouthed to the wall plates. In this case the weight of the roof and its covering is thrown obliquely upon the wall, but the tendency to overturn is lessened as the pitch of the roof is increased. It is not recommended to adopt the couple roof in spans exceeding 12 ft. See Fig. 2, page 140.

Collar Roof.—The diagram furnished by Fig. 3, page 140, shows this roof in its simplest form. When the span is greater than 12 ft., the timbers need tying together. The tie in this case is placed half-way up the rafters, and in this position is known as a "collar." An elaborate form of this roof with trusses is sometimes used in Gothic structures, and the increased span is provided for by means of brackets or ribs. See page 159.

Couple Close.—When the feet of the rafters are tied together horizontally, as in Fig. 4, page 140, they are said to be closed; and the arrangement of the roofing timbers in this manner is known as a "couple close." In the smaller spans the wall plates are tied at intervals of every 3 or 4 feet; but if ceilings are attached, then each closing piece forms a ceiling joist, and needs to be spaced at about 12 inches apart. In long spans, from 16 to 18 feet, and where ceilings are

Line Diagrams of Timber Roofing

Indicating Method of Treatment
in
Relation to Span



attached, the ceiling joists need to be supported at their centres by iron rods.

King-post Truss.—In the foregoing examples common rafters only were used, but in spans from 18 ft. upwards trusses or principals are necessary; that at Fig. 6 is known as a "king-post truss," suitable for spans from 18 to 30 ft. A full elevation of this truss is shown on page 142, with common rafters, ridge piece, purlins, and pole plates added.

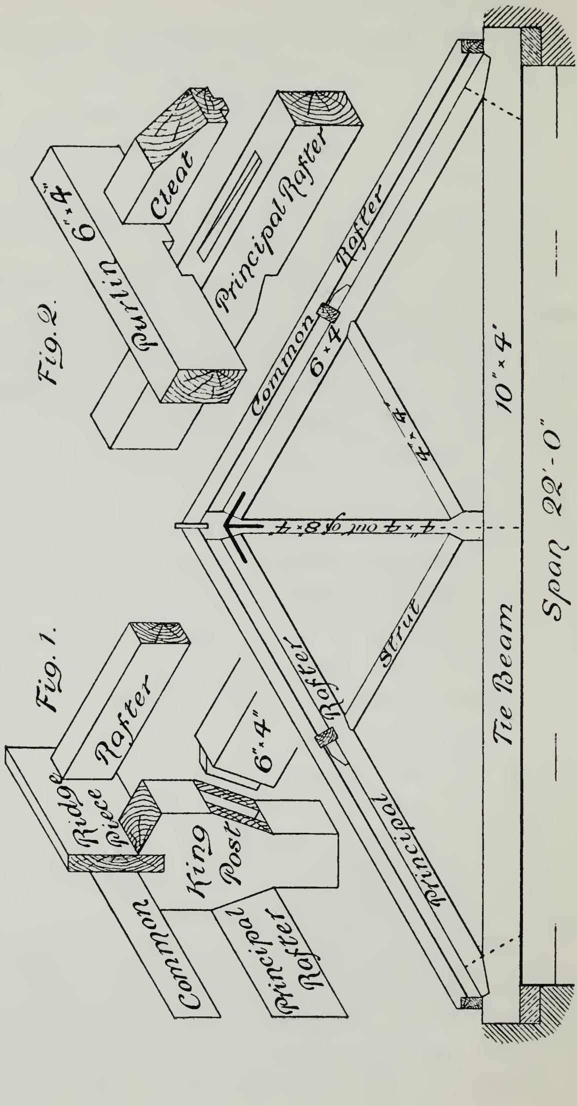
It will be seen that the king-post truss is composed of principal rafters, tie-beam, king-post, and struts. These, when framed together, complete the truss or principal.

The advantage of trussing is that, by its means, the weight of the roof is carried vertically upon the walls.

The trusses should be arranged to span the building at intervals of from 8 to 10 feet, and between them are carried the ridge piece, purlins, and pole plate; to these are fixed the common rafters, which, in their turn, carry the roof covering. Thus the weight is carried, first, by the common rafters to the ridge piece, purlins, and pole plate, and, by them, concentrated at their junction with the principals.

The detail of the joint at the head of the king-post is shown by the enlarged sketch at Fig. 1, whilst the joint at the purlin is shown at Fig. 2. To prevent the purlin from being turned over, short pieces, called cleats, are partially sunk into the top or back of the principal rafter, and spiked or bolted.

In order that the nature of the stresses in the various members may be understood, we will build up the truss in sections. First, place the two principal rafters in position upon the wall, and consider that a load has been placed at the apex or head. The load has a



King-Post Truss

tendency to push the walls out; to prevent this, place the tie-beam in position, making good the joint between it and the principal rafter. It will now be seen that, if the tie-beam and its joints are strong enough, the feet of the rafters are kept in position. We may infer from this that the principal rafters are in compression, and the tie-beam is in tension. Now, place the loads at points half-way up the principal rafters (the position of the purlins), and, if the loads are heavy enough, the rafters will be seen to bend or sag, and approach a point near the centre of the tie-beam. To prevent this, place the two supports or struts in position, passing from the centre of the tie-beam up to the centres of the principal rafters. It will now be seen that the weights at the purlins are conveyed across the principal rafter and down the strut to the tie-beam, and the principal rafter bends only as the tie-beam is bent. Now, place the king-post in position, supported at the head between the rafters, and allow the struts to rest against the enlargement at the base. If the king-post is strong enough, and the joints are properly constructed, it will be found capable, not only of holding in suspension the weight carried along the struts, but also of assisting to carry the tie-beam with its load. If the king-post were constructed of material sufficiently elastic, we should find it stretched by the weight; it is therefore in tension. The following is a summary of the results:

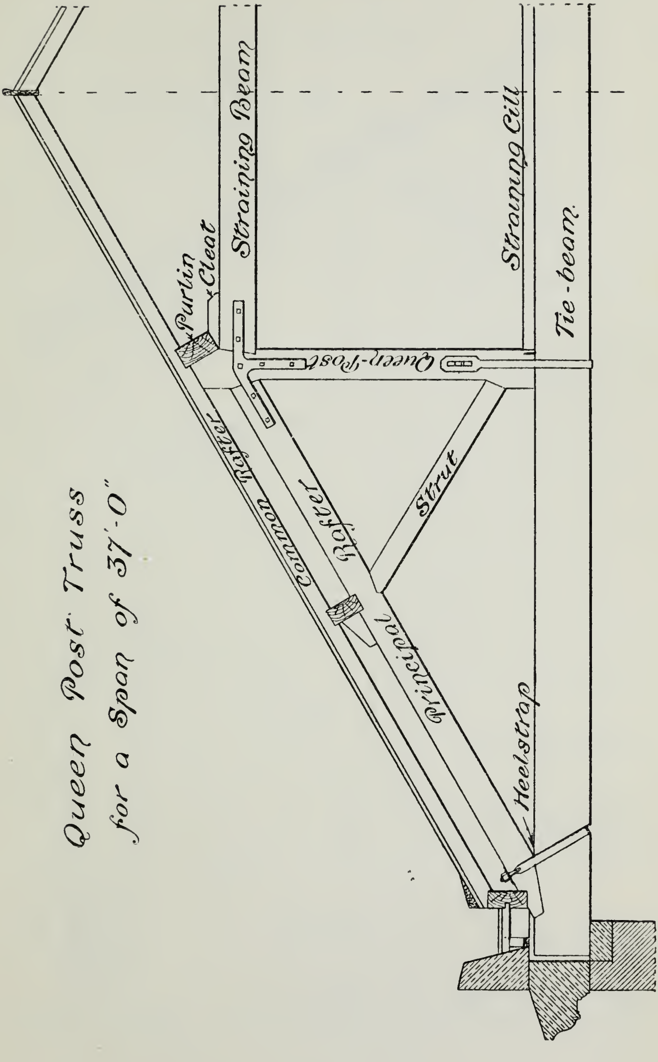
Member.	Nature of Stress.
Principal Rafters, - -	Compression.
Struts, - - - -	Compression.
Tie-Beam, - - -	Tension.
King-post, - - -	Tension.

Camber. — Horizontal timbers, however straight they may be previous to being placed in position, have a tendency to deflect or sag in the centre, even from their own weight. This is very noticeable, and gives the impression of weakness. Even a small deflection appears to the eye to be much more than is actually the case. To counteract this, beams, bressummers, joists, etc., should be placed with their rounded edges uppermost, and in framed timbers an allowance, known as "cambering," should be created.

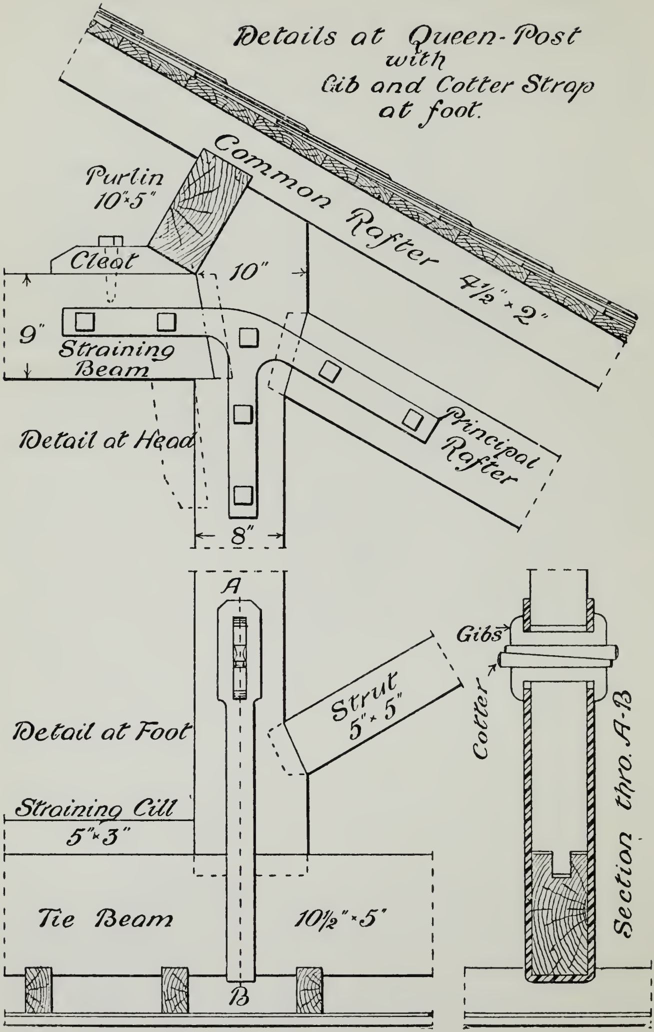
Arching or cambering the timbers was at one time considered to give increased strength; this may have been so at a time when walls were built stout enough to withstand the oblique thrusts, but in modern construction it is far from being the case. As an arched or cambered beam assumes the straight line, it has a tendency to thrust outwards its supports, so that care must be exercised that the camber is not too great.

Cambering the tie-beams of wood trusses has the effect of reducing the subsequent settlement of the structure. The king- or queen-posts are, for this purpose, cut short to the extent of 1 in. or 1¼ in. for every 20 ft. in the length of the span. This has the effect, when the shoulders have been drawn up, of tightening all the joints throughout the truss, so that any subsequent settlement due to this cause is prevented.

Queen-post Truss.—When the span exceeds 30 ft., two vertical posts are used instead of one; these are known as "queens," and the truss is called a "queen-post." Page 145 contains a part elevation of a queen-post truss for a span of 37 ft., whilst enlarged details are shown on pages 146, 148, 149, and 151.



Queen Post Truss
for a Span of 37'-0"


Details at Queen-Post
with
Gib and Cotter Strap
at foot.
Common Rafter 4½" × 2"
Purlin
10" × 5"
Cleat
10"
9"
Straining
Beam
Principal
Rafter
Detail at Head
8"
A
Gibs
Cotter
Strut
5" × 5"
Detail at Foot
Straining Cill
5" × 3"
Tie Beam
10½" × 5"
B
Section thro. A-B

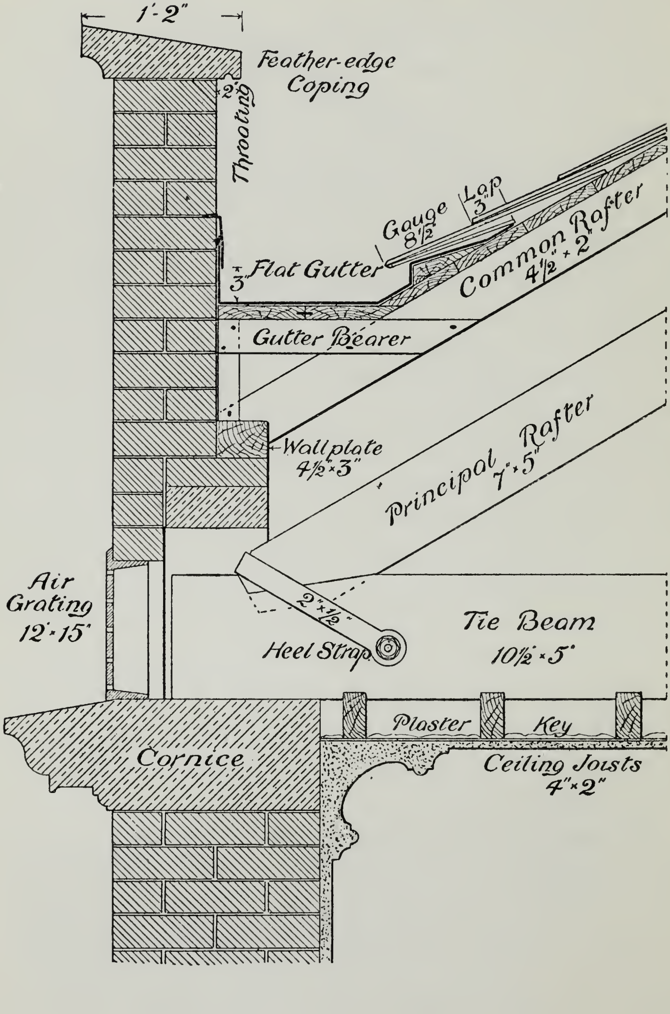
The joints around the head and foot of the queen-post are shown on page 146, with the necessary ironwork, that at the foot being known as the gib and cotter joint.

The method of using the gib and cotter strap will best be seen in the section, page 146. The strap passes underneath the tie and up the sides of the posts. A mortise is cut in the latter in a position slightly above the holes provided in the enlarged ends of the strap. Iron gibs of the form shown in the figure are then inserted, the ears keeping the strap in position whilst the iron wedges or cotters are driven. It will be seen that the gibs are in contact with the iron strap at the top, and with the wood post underneath. The driving of the cotters has the effect of opening out the gibs; these in their turn press against the strap at the top, lifting it, and bringing up the tie-beam with it, whilst the cotter below presses against the post, keeping it down and consequently closing the joint. The gib and cotter strap may be applied in the same way to king-posts, and to the support of sills in the framing of partitions.

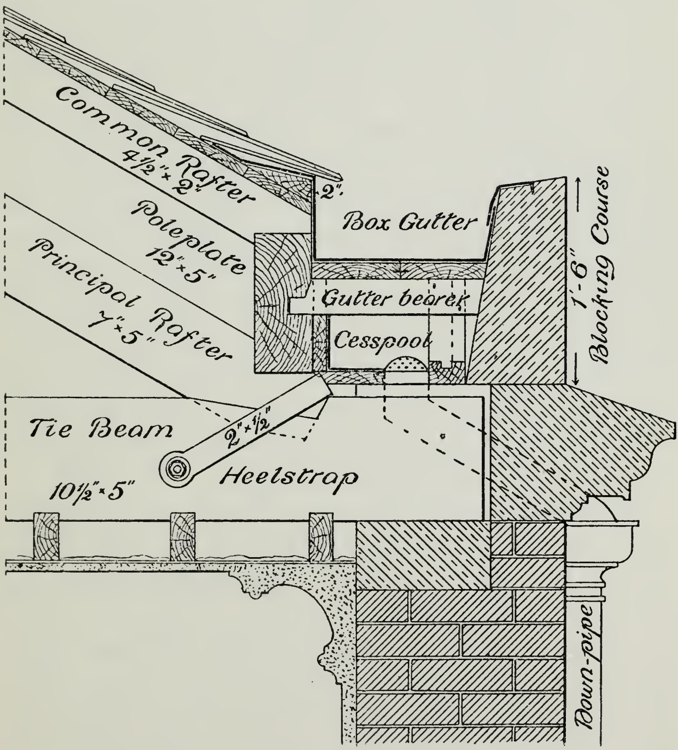
Roof trusses are placed at distances governed by surrounding circumstances usually 8 or 10 feet. Where this dimension is exceeded, the purlins require to be greatly strengthened either in their scantling, or by trussing or strutting.

Parapet Gutters.—The section given on page 148 shows the method of treatment of the timbers at the foot of the principal rafters when a flat gutter has to be formed against a parapet. In this case the gutter bearers are notched over and spiked to the common rafters, the latter resting upon a wall plate. Pockets

Detail at Parapet.



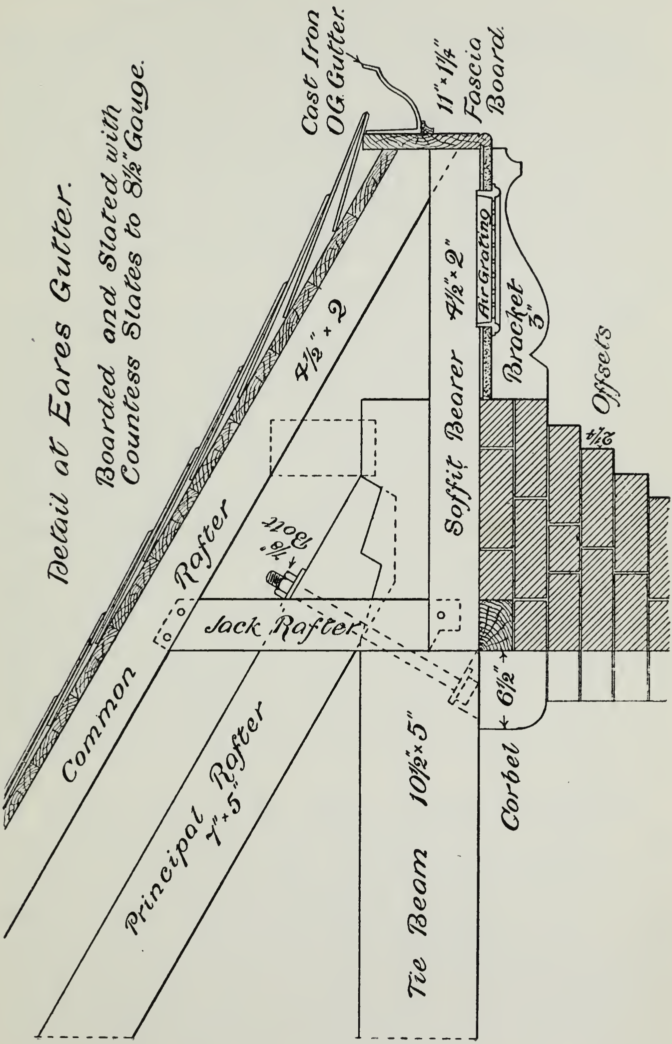
Detail at Gutter.
Blocking Course Finish with Box Gutter and Cesspool



have here been provided for the reception of the end of the truss, and provision made for the ventilation of the roofing timbers, by placing an air grating just above the cornice. The flow is given to the gutter in this case by varying the height of the gutter bearers; this necessarily makes the gutter wider as the height of the bearer increases.

Box Gutters.—The section on page 149 gives the method of forming a box gutter. The pole-plate is made use of here, for the purpose of carrying the ends of the common rafters, instead of the wall plate, the essential difference between the two being that the wall plate rests throughout its length upon the wall, whilst the pole plate rests only at intervals upon the ends of the roof trusses. The full depth of the pole plate is here taken advantage of for the varying height of the gutter bearer, the ends of which are tenoned into its sides, forming an approximately parallel gutter. The cess-pool is a form of tank or cistern for the purpose of collecting or receiving the rain-water previous to its being emptied into the down-pipe; it may be formed within the depth of the tie-beam, where the position of the latter does not prevent it.

Eaves Gutters.—These are illustrated on page 151. The roofing timbers are carried over the edge of the wall at least 18 ins., the common rafters being supported either by jack rafters or by a pole plate. Soffit bearers are carried out from the wall, and made fast to the ends of the common rafters, the ends being closed or covered by a fascia board. It is to the fascia board that the gutter is fixed, the depth of the former allowing the gutter to be fixed with the necessary flow. The soffit is covered either by boarding or lath and

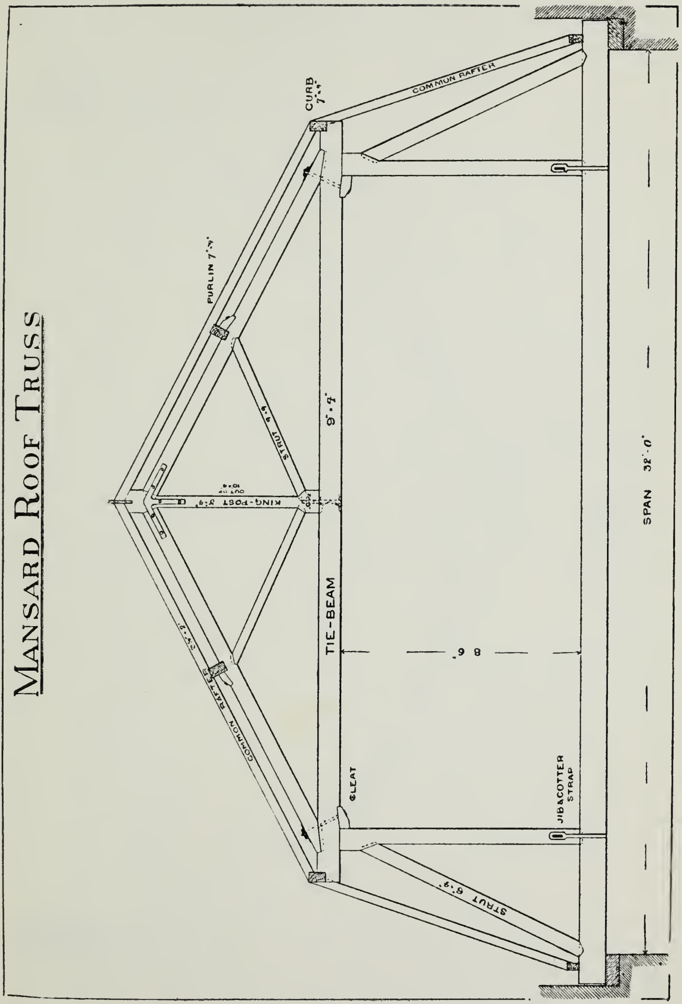

Detail at Eaves Gutter.
Boarded and Slated with Countess Slates to 8½" Gauge.
Cast Iron O.G. Gutter.
11" × 1¼" Fascia Board.
Air Grating
Bracket 3"
Offsets
2¼"
4½" × 2
Soffit Bearer 4½" × 2"
Common Rafter
Principal Rafter 7" × 5"
Jack Rafter
⅞" Bolt
Tie Beam 10½" × 5"
Corbel
6½"

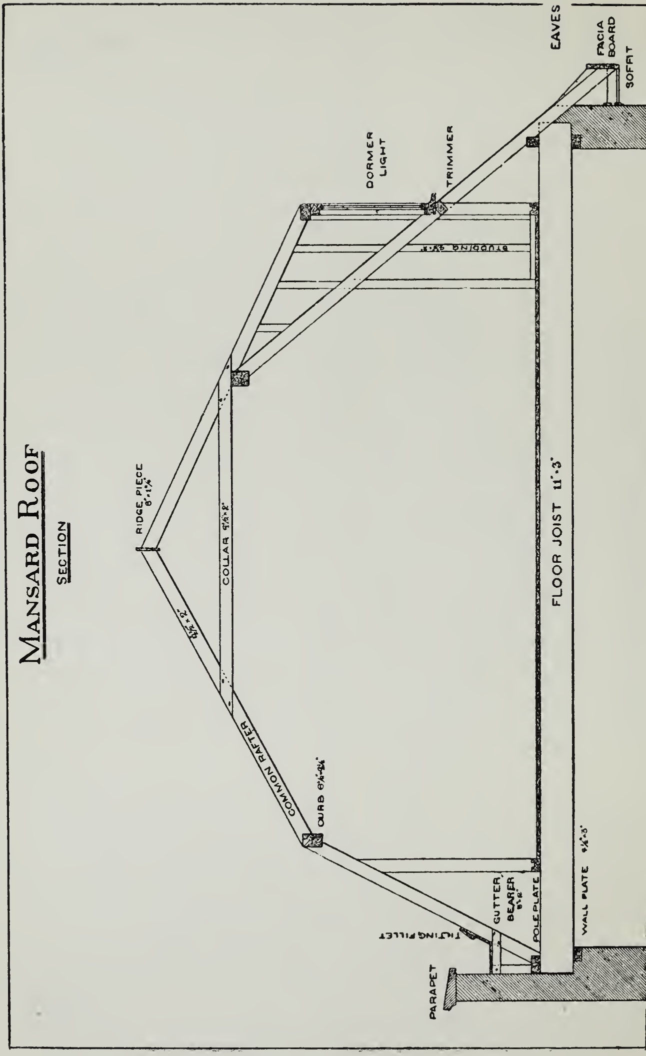
plaster; whilst at intervals air gratings may be fixed for the purpose of ventilating the roof timbers.

Abutments.—These are formed by increasing the thickness of walls immediately underneath bearing timbers, when increased support is required; corbels or brackets of stone are also used for the same purpose. By a slight alteration of the scantling, the details at the foot of the principal rafter, as given on pages 148, 149, and 151, may be adapted both for king- and queen-post roof trusses.

Mansard Roofs.—On page 153 is shown a complete elevation of a mansard roof truss, with common rafters, purlins, curbs, and pole plates added. It is a combination of king- and queen-post trusses, with two roof planes on either side. The advantage of this form of roof is that increased accommodation may be obtained without the expensive construction of walls. It is a common occurrence on the Continent to find several tiers of rooms within the roof itself. The section given on page 154 shows how a similar form of roof may be constructed upon purlins without the use of a truss. It is intended here to finish with parapet wall at the front, and with overhanging eaves gutter at the back.

Philibert-de-Lorme Truss.—The truss shown on page 156 is an illustration of what is known as a "Philibert-de-Lorme" truss. The main rib is formed up of a series of short lengths of boards in three thicknesses, placed vertically, and with butt joints. These are stiffened by being fastened with radiating pieces to a blade of 11 in. by 4 in. material and to the uprights. The radiating pieces are made slightly ornamental in character, whilst the top five are made to


MANSARD ROOF TRUSS
COMMON RAFTER
CURB
PURLIN
STRUT
KING-POST
TIE-BEAM
CLEAT
JIB & COTTER STRAP
SPAN 32'·0"


MANSARD ROOF
SECTION
EAVES
FACIA BOARD
SOFFIT
DORMER LIGHT
TRIMMER
STUDDING
RIDGE PIECE
COLLAR
FLOOR JOIST 11"·3"
COMMON RAFTER
CURB
GUTTER BEARER
TILTING FILLET
POLE PLATE
WALL PLATE
PARAPET

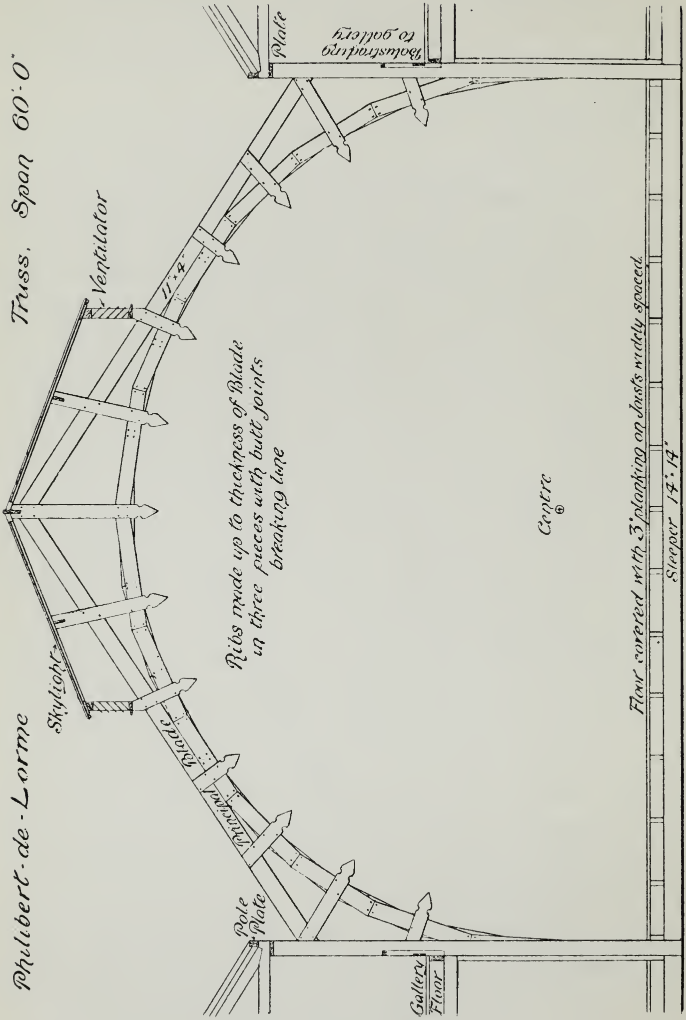
support the skylight and ventilators. The truss, as here constructed, is intended for temporary use only. The strength of curved ribs of this kind, as compared to a solid rib, is equal to one of the same breadth and thickness, less one rib.

Colonel Emy Truss.—Another form of truss with laminated ribs is that shown on page 157. In this case the boards or laminations are concentric and cylindrical, well bolted together. These are built upon a rough platform or "centre," the boards being forced to "take up" the curve by means of cramps. It is, however, found that when the laminations are thoroughly jointed at the butts, and kept well together by bolting, the tendency to spring, on being released, is but little. And this is entirely counteracted by the subsequent external bracing and strutting.

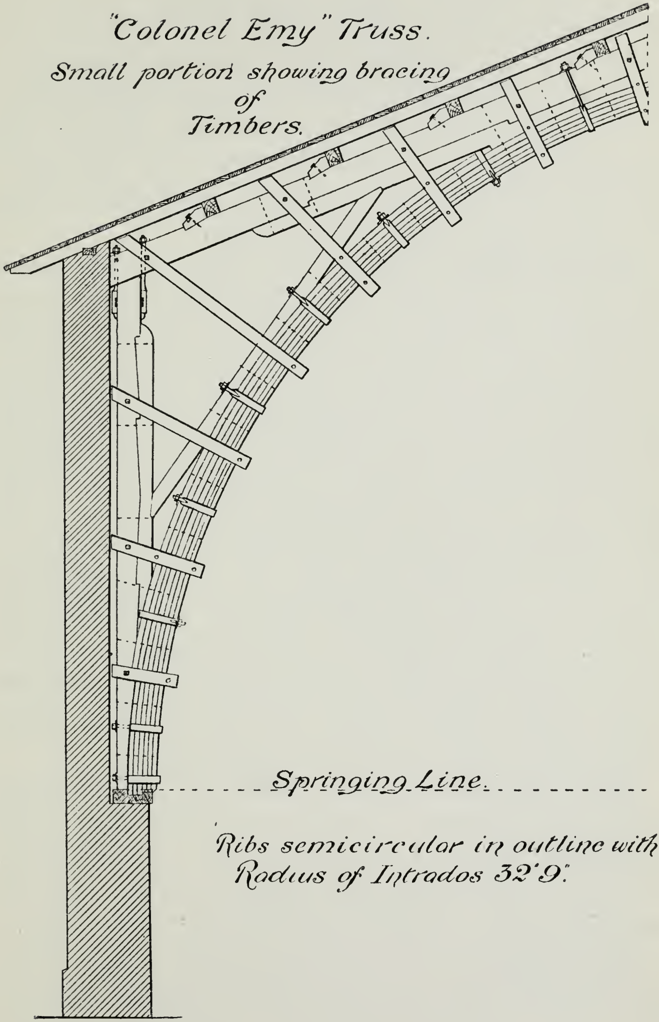
This method of building up ribs by laminations adapts itself admirably well to the construction of bridges and large roofs, where economy and strength are the chief considerations.

Gothic Roofs.—The truss illustrated on page 159 is an adaptation of the collar beam mentioned in the previous part of the chapter. The collar is secured to the principal blade by a stump mortise and tenon, and by means of a collar strap with bolts. The tendency of roofs of this description is to push the walls outward, the angle at the collar opening, whilst that at the foot of the rafter closes.

The ribs, which for the sake of economy are built up in sections, are made fast to the blades and collar and to each other by means of small purpose-made oak tenons about 8 in. long and 4 in. wide, firmly draw-bore-pinned with $\frac{3}{4}$ in. or $\frac{7}{8}$ in. oak pins or tree-nails,



Philibert-de-Lorme Truss. Span 60'·0"

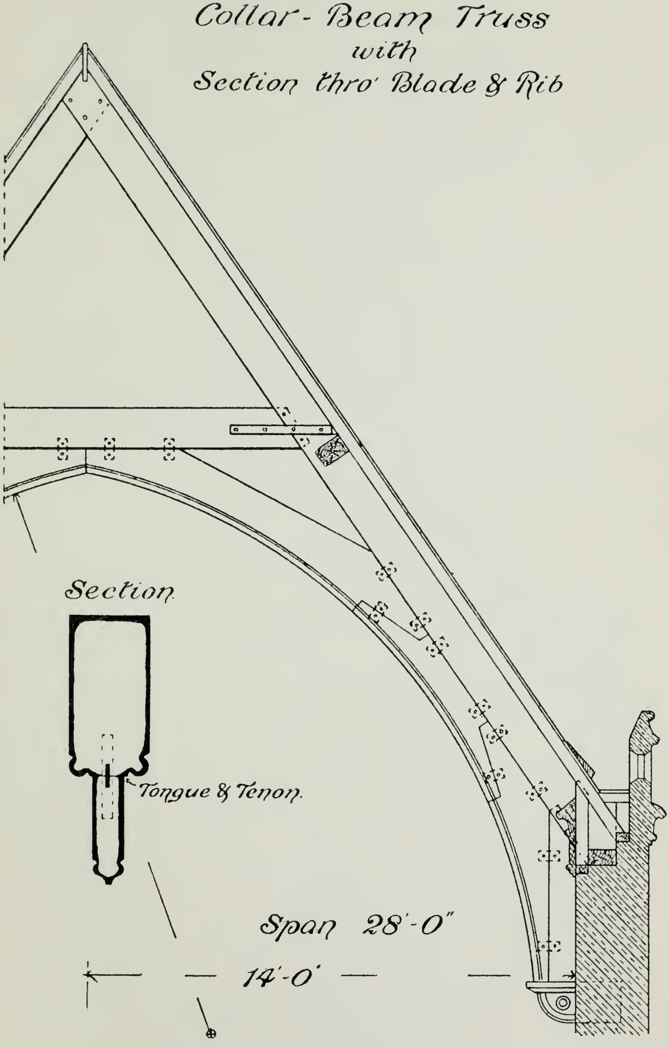

"Colonel Emy" Truss.
Small portion showing bracing of Timbers.
Springing Line.
Ribs semicircular in outline with Radius of Intrados 32' 9".

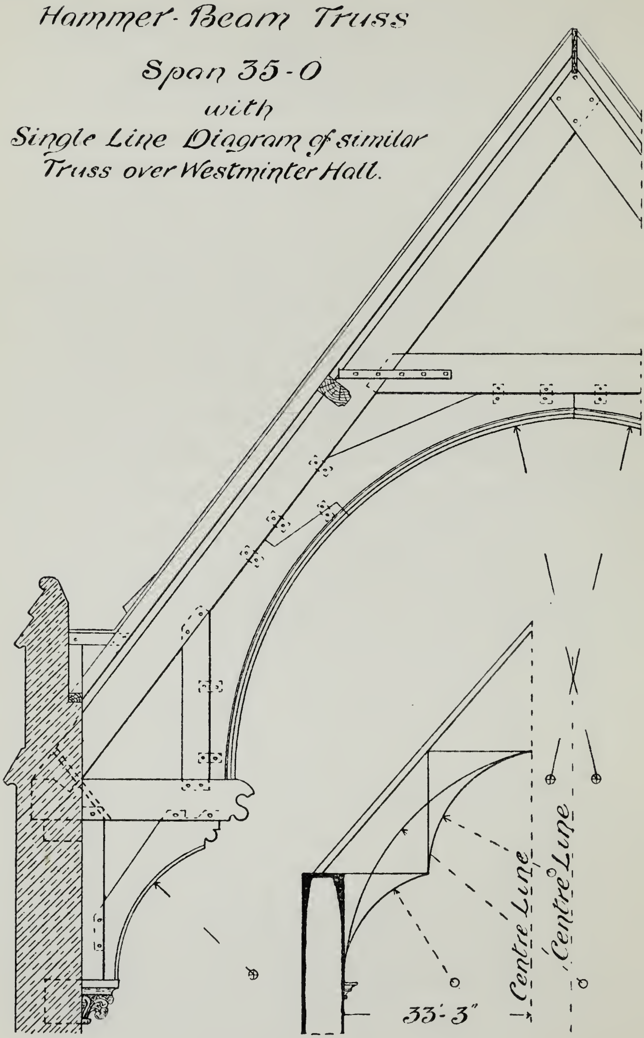
The joints between the ribs are spliced, and these, and their joints with the blades, are tongued, as shown in the enlarged section. The blades in this example are 11 in. by 5 in., whilst the ribs are $2\frac{1}{4}$ in. thick. It is desirous, in roofs of this kind, to carry the timbers to as low a point in the wall as is possible. In this case an upright plate has been attached to the lower end of the blade, and this, with the rib, has been carried down to a stone corbel, upon which it rests.

Hammer-Beam Truss.—This truss is illustrated upon page 160, the short horizontal hammer-beam coming out from the foot of the principal rafter giving the truss its name. Trusses of this kind lend themselves to elaborate ornamentation, the spandrils being filled with tracery panels, and the ribs and blades moulded to such an extent that the outline of the principal timbers is, in some examples, almost lost to view. The diagram represented at the bottom of the page is that of the hammer-beam roof over Westminster Hall, reputed to be the best example of its kind in the country. Three main ribs are here made use of on either side of the centre, one passing directly from the centre of the collar, whilst the others pass in either direction from the end of the hammer-beam.

Wind Braces.—In lofty trusses of the foregoing kinds, it is necessary to afford some additional lateral support in order to keep them in a vertical plane. These are usually placed in the plane of the roof, and pass, in the form of ribs, from one truss to the other.

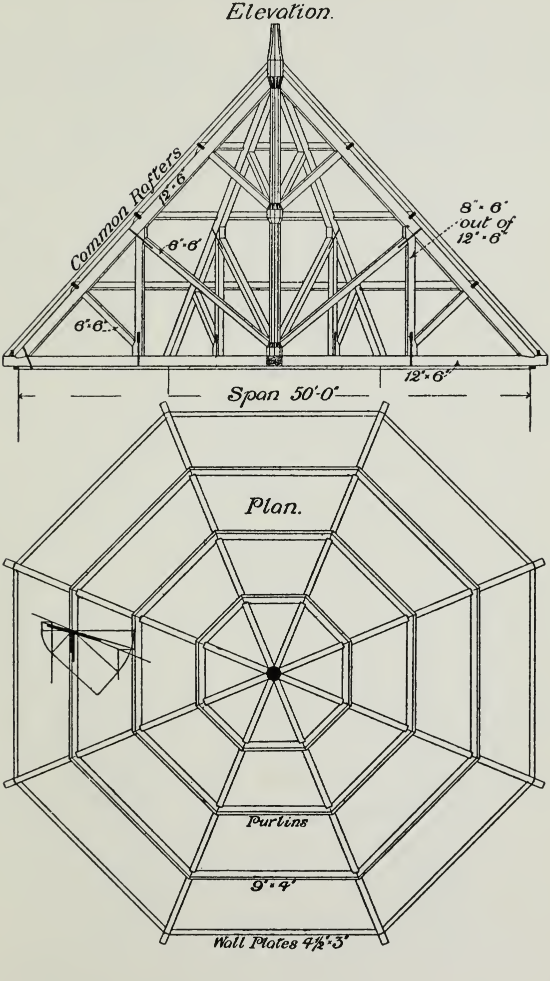
Turret Roofs.—The illustration given on page 161 is that of a pyramidal or turret-shaped roof, octagonal in plan. The principal rafters are supported at three points by strutting, two passing from the centre


Collar - Beam Truss
with
Section thro' Blade & Rib
Section
Tongue & Tenon.
Span 28'-0"
14'-0'


Hammer-Beam Truss
Span 35-0
with
Single Line Diagram of similar
Truss over Westminter Hall.
Centre Line
Centre Line
33'-3"

Octagonal Roof

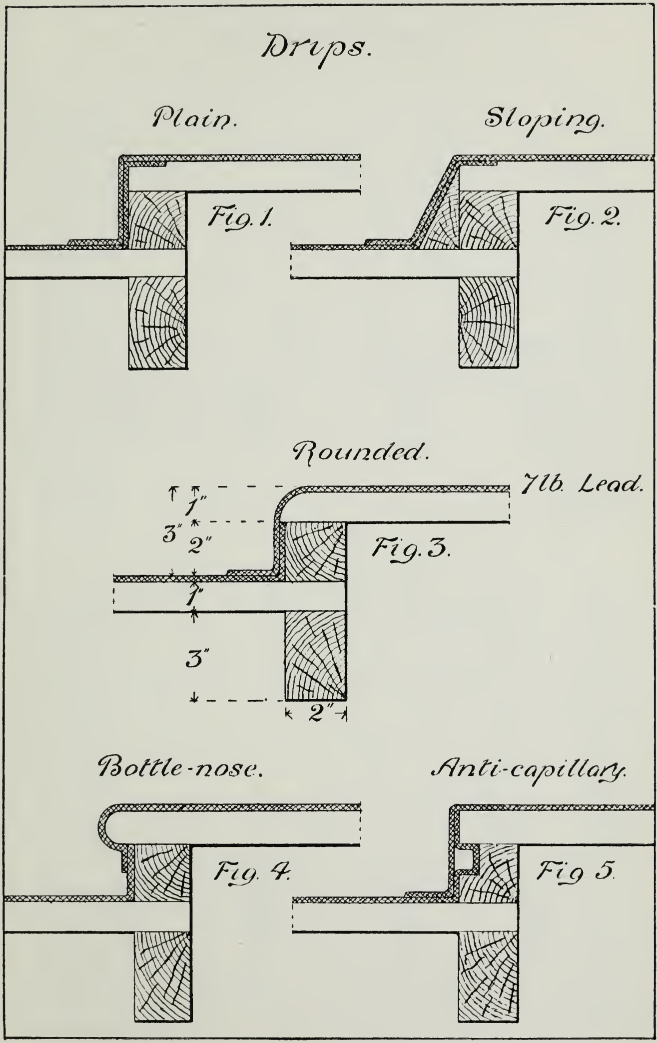
PLAN WITH SECTIONAL ELEVATION.

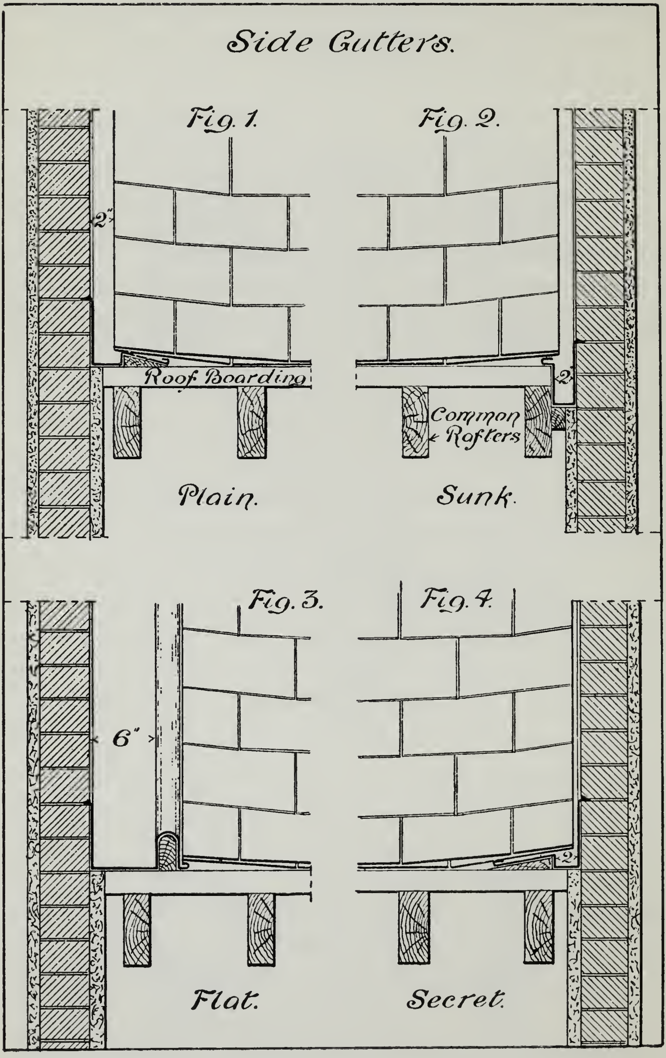


post, whilst the third passes up from the foot of the queen-post. These latter are made fast to the ties by gib and cotter straps, whilst additional support may be given to the struts by fixing short cleats on the off-side of the queen-posts.

Drips.—In arranging gutters, consideration must be made for the covering material. If that material be lead, then the gutter should be arranged, as nearly as possible, in 7 ft. lengths. In practice it is found more convenient to work the lead in lengths not exceeding this dimension. At these distances drips are arranged which afford an opportunity of joining the lengths in such a manner that, although kept in position, they are free to shrink and expand with the changes of temperature. Page 163 contains five methods of forming the drip. Fig. 1 represents what is known as a plain drip. The lead is worked up from the lower to the higher level, and tacked to a rebate. This is the fixed end, the other being arranged—as the top piece of lead—to move freely with the expansion and contraction, without buckling. Fig. 2 represents a sloping drip, the advantage of this form being that the lead is more easily bossed at the ends. Fig. 3 represents a rounded drip. In this case the lead is not so easily cut through in walking over it, as with the square edge. The section given in Fig. 4 has the advantage of preventing the lead from rising when the gutters are wide. The section of Fig. 5 has been arranged to prevent the passage of water through the lead joint by capillary attraction, a peculiar property of fluids explained in the previous chapter.

Side Gutters.—Sections, with part elevations, are shown on page 164, of the various forms of gutters con-


Drips.
Plain.
Sloping.
Fig. 1.
Fig. 2.
Rounded.
7lb. Lead.
1"
3"
2"
Fig. 3.
1"
3"
2"
Bottle-nose.
Anti-capillary.
Fig. 4.
Fig 5.

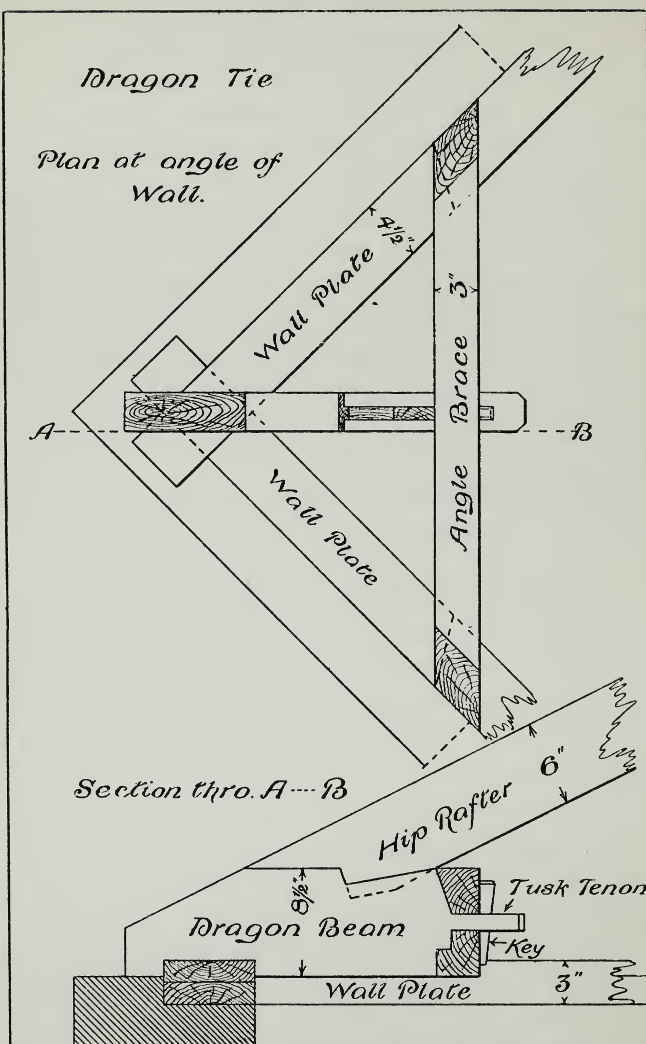

Side Gutters.
Fig. 1.
Fig. 2.
2"
Roof Boarding
2"
Common
Rafters
Plain.
Sunk.
Fig. 3.
Fig. 4.
6"
2"
Flat.
Secret.

structed upon the sloping sides of roofs to make water-tight their junction with rising stacks or gable-ends. The sections in each case are taken through stacks or chimney flues, the inside of the $4\frac{1}{2}$ in. being parged, whilst the outside has been rendered, this latter precaution making it doubly secure against fire.

Dragon Ties.—In hipped roofs it is often found desirable to give additional support to the wall plates, and to secure a better seating for the hip rafter than the wall plates afford. This is accomplished by first bracing the wall plates together, as shown on page 166, and then to tenon a dragon beam to its centre, notching it at the back to the tops of the wall plates. The arrangement of the timbers in this manner is known as a "dragon tie."

Roofing Irregular Plans.—Great difficulty is sometimes experienced in arranging the roofing of buildings irregular in plan; page 169 contains two such examples. The difficulty is sometimes overcome by inclining the ridges, and sometimes the eaves, or in some cases the roof plane has been twisted to meet the irregularity, neither of which is considered to produce a good effect. Figs. 1 and 2 represent two irregular plans. In the first case two of the walls are parallel, and, being the long walls, the ridge may be made parallel to them, and the ends hipped to meet it. The positions of the trusses are marked by double dotted lines.

The irregular plan given in Fig. 2, page 169, offers the greater difficulties of the two. If the planes of the roof are to be true, and the ridges and eaves horizontal, the only position which the plans of the ridges can occupy is parallel to the wall plates. If four

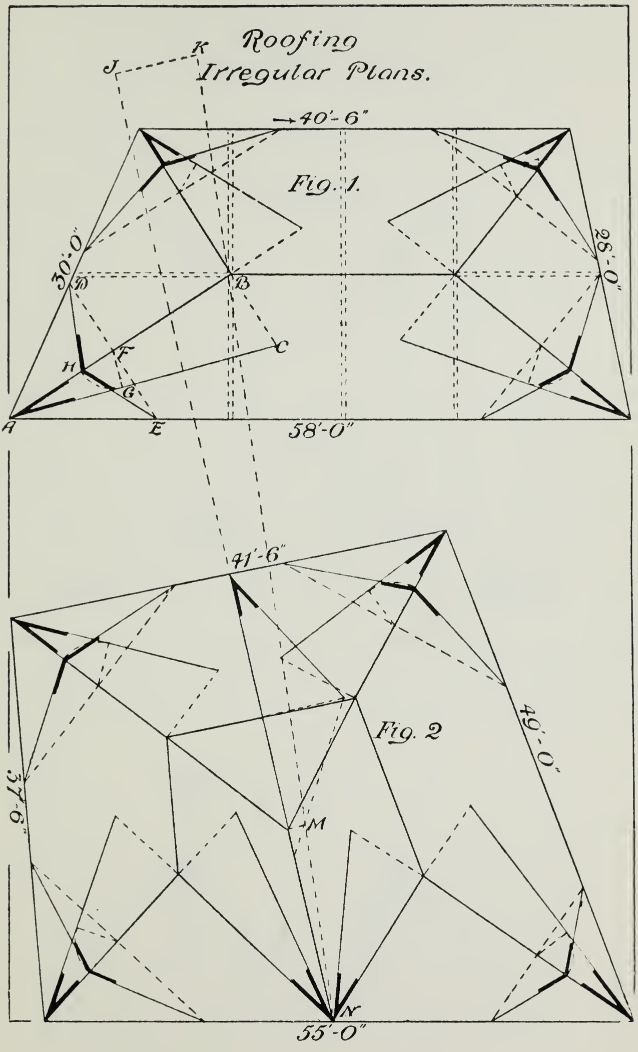

Dragon Tie
Plan at angle of Wall.
Wall Plate
4½"
3"
Angle Brace
Wall Plate
A
B
Section thro. A---B
Hip Rafter
6"
8½"
Tusk Tenon
Dragon Beam
Key
Wall Plate
3"

ridges were adopted, then the means of draining the central portion would be intercepted. The method adopted here is to make use of the upper three ridges only, allowing the water collected between them to drain to the lower wall. To draw the plans of the valleys, consider the side ridges produced until they intersect in point J (at the top of the page), and draw JN, bisecting the angle at J and intersecting the lower wall line in N. This line may be considered as the plan of the valley gutter between the ridges. By developing this inclined valley line with the outline of roof, as shown by the dotted lines, the intersecting joint M is obtained, its plan being immediately below it. Then by joining up the plan of this point with the intersections of the ridges, the plans of the two remaining valleys are obtained. The lengths of the hips and the bevels of their backing are shown in this example, the methods adopted being explained in the following.

To find the Length of the Hips.—The hips may always be considered as occupying the position of the hypotenuse of a right-angled triangle, the plan of the hip being its base, and the difference in the altitude of the highest and lowest points of the hip, the perpendicular. If these lines be rotated about the plan, into the horizontal plane, the length of the hip may readily be obtained. In Fig. 1, page 169, AB represents the plan of the hip, and BC the difference in their altitudes. By turning down BC at right angles to BA, then AC represents the true length of the hip. This process has been repeated with each one of the hips in Figs. 1 and 2.

To find the Backing of the Hip or the Angle between the Planes of the Roof.—The dihedral

angle between the two roof planes is measured by a third plane, mutually perpendicular to the first pair; the angle between the lines of intersection represents the angle required. For this purpose, the horizontal plane is brought up to the level of the wall plates, the plans of the latter being represented by a single line. The plane used for measuring the dihedral angle is always triangular, and made up by the two lines including the required angle and the line which is the horizontal trace of the plane. Of this triangle three elements are sought for the purpose of its construction, viz., the base, perpendicular, and the position of that perpendicular. Taking the same corner as used in the last case, Fig. 1, we will proceed to find the angle contained between the planes intersecting in the hip of which *AB* is the plan. In order that a plane shall be perpendicular to two others, its horizontal trace must be at right angles to the plan of the line of intersection. The dotted line *DE* is therefore drawn at right angles to *AB*, and represents the base of the triangle already alluded to. Its intersection (*F*) with *AB* is also the position of the foot of the perpendicular. To find its length, take a side view of the hip or intersecting line (*AC*). If from *F*, a line be drawn perpendicular to *AC* and intersecting it in *G*, then *FG* represents the length of the perpendicular. With *F* as centre and *FG* as radius, construct an arc cutting *AB* in *H*. Then *FG* (the length of the perpendicular) is rotated into a position at right angles to *DE*, and the angle *DHE* is the angle required. The plan being irregular, the angles will all differ; the operation therefore requires to be repeated at each corner.


Roofing
Irregular Plans.
J
K
40'-6"
Fig. 1.
30'-0"
28'-0"
D
B
C
F
H
G
A
E
58'-0"
41'-6"
Fig. 2
49'-0"
37'-6"
M
N
55'-0"

Purlins and Jack Rafters method of obtaining Bevils

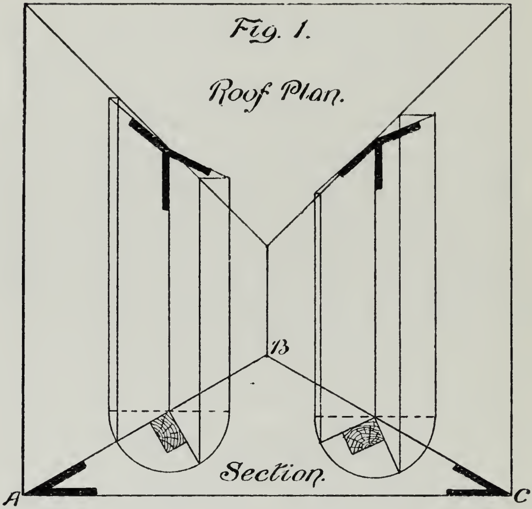


Fig. 1.

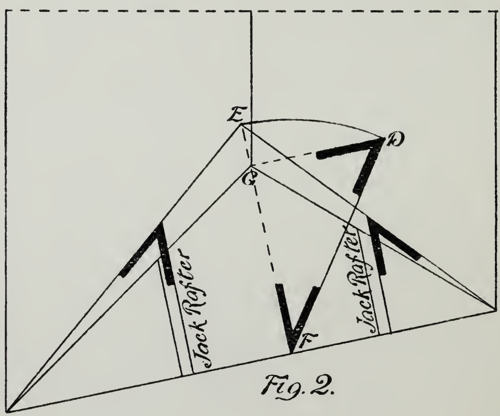


Fig. 2.

To find the Bevels for Purlins.—Fig. 1, page 170, may be considered as a portion of the plan of a regular-shaped building, and *ABC* a section through its roof planes. Two enlarged purlins are represented in section, each placed at different angles to the roof plane. For the purpose of obtaining a larger diagram, the sides of the purlins have been increased to a width equal to the length of the radii of the circles. The extremities of these radii have been carried back to the plans of the hips. The ends of the surfaces when developed represent geometrically the true bevel upon the ends of the material.

To find the Bevel of the Jack Rafters.—The irregular end of a building has been selected for this example, and is shown at Fig. 2, page 170. The double lines represent the plans of jack rafters (shortened rafters). The perpendicular distance from the eaves to the ridge has been found by developing the pitch *GFD*, and then turning it into the horizontal plane at *EF*. One each of the margin lines of the jack rafters have been produced to meet the hips developed. The angles between these lines represent those required.

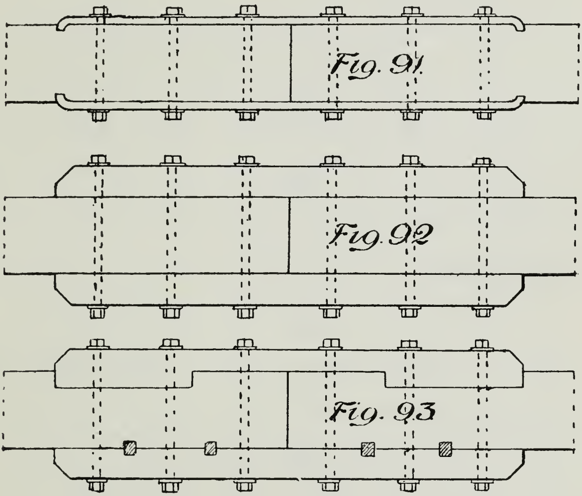
CHAPTER IX.

FISHING, SCARFING, AND TRUSSING TIMBERS.

In some of the larger varieties of framing which the carpenter has to construct, it is often a difficult matter to procure timbers of sufficient length for his requirements. He has, therefore, to resort to one or other of the following means, viz., fishing or scarfing. The essential difference between the two being that, in making a fished joint, the breadth or depth of the timber is increased; whilst in scarfing, the joint is constructed within its own breadth and depth.

Fished Joint.—In these joints no part of the length of the timber is lost. For this reason, and for the fact that they require little labour to construct, it is considered the most economical method of lengthening timbers. They may be constructed for compression, tension, and for transverse stress. Fig. 91 is intended to resist compression; it is the neatest of the fished joints, as the plates do not project much beyond the thickness of the material. Another fished joint, designed to resist compression, is that shown at Fig. 92, in which case wood fish plates have been used. It has been said that the strength of these joints is equal to the strength of the fish plates; but

the fact must not be lost sight of that the plates are placed in the most effective position, and are, comparing equal sections, far more powerful here than in the centre of the depth of the timbers. Fig. 93 is designed to resist both compression and tension. As a tensile joint, its strength depends upon the ability of the material to resist shearing, both with respect



to the wood and iron. On the under side of the figure, the butt is prevented from opening by the hard-wood keys or cogs. The top plate is said to be tabled. A good joint for the purpose of resisting transverse stresses may be constructed by sinking a wood fish plate a little below the surface of the side in compression, and by placing an iron fish plate upon the tensile side, and bolting the whole well together. The bolts should be placed zigzag, to preserve, so far as possible, the effective area of the material. The fish plates are

Fig. 1.

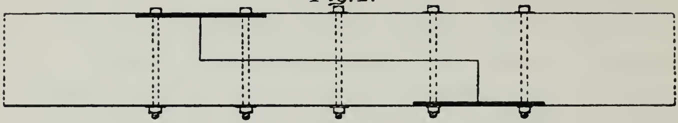


Fig. 2.

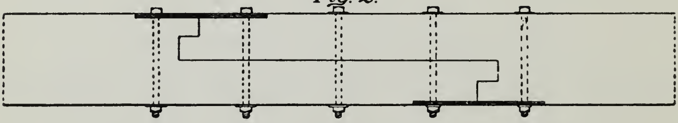


Fig. 3.

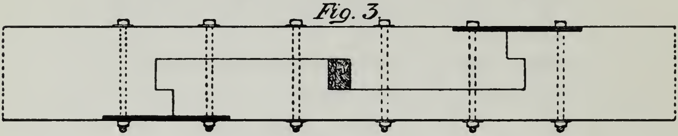


Fig. 4.

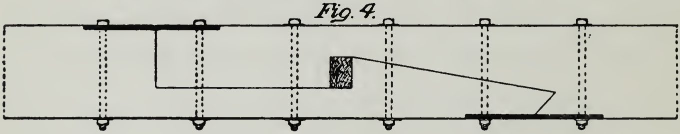


Fig. 5.

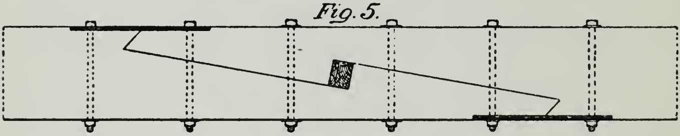


Fig. 6.

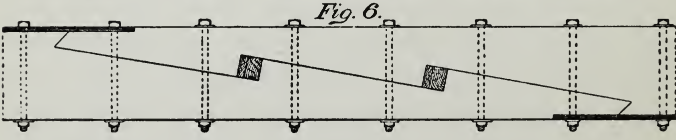


Fig. 7.

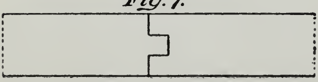
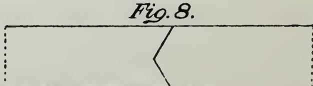


Fig. 8.



of a length equal to six times the depth of the piece joined.

Scarfing.—Figs. 1 to 6, page 174, are representations of scarfing for tension, compression, and transverse stresses. In each of these cases, each piece is cut away to the extent of the length of the scarf. Fig. 1 represents a scarf suitable for compression only. Fig. 2 is an illustration of an example intended to resist both compression and transverse stresses. Figs. 3 and 4 are designed for a similar purpose. Figs. 5 and 6 are designed for the purpose of ties, and are also calculated to resist transverse stresses. Figs. 7 and 8 are given to represent the method of finishing the top and bottom edges of the foregoing examples when they are subject to side thrusts. Fig. 7, of the two, is calculated to be best adapted for compression joints, the bearing surfaces being at right angles to the direction of the thrust.

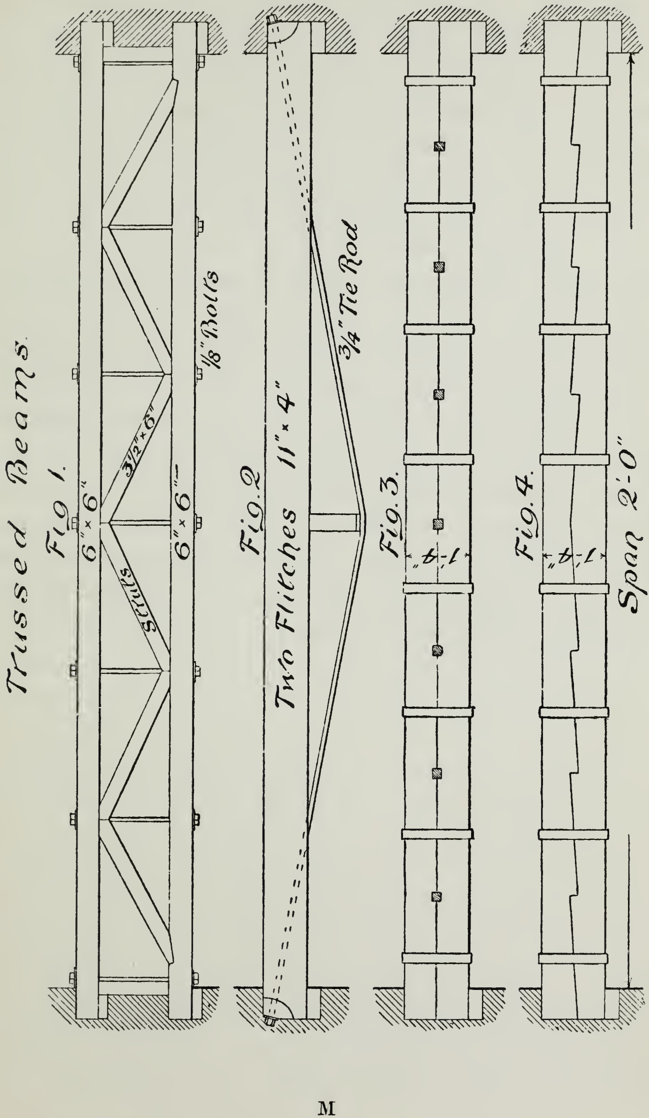
Strengthening Horizontal Timbers.—For this purpose a series of timbers may be built up at the side of each other, the strength of such timbers being increased directly as the number of the pieces used. If bolted together in a manner somewhat similar to the flitched beam (Chapter IV.), they are rendered considerably stronger, the strength increasing directly as the breadth. Timbers placed above each other, if properly designed and secured, are even stronger than those placed side by side. This will be easily understood from the fact that the strength of rectangular timbers varies directly as the square of the depth. Upon examination of Fig. 94, it will be seen that the pieces or laminæ, of which the whole beam is composed, is liable to slide over each other as

they are deflected or bent down. This must be prevented, if the fullest effect of the increased depth is to

Fig 94

be secured. In Figs. 3 and 4, p. 177, sliding is prevented by cogging or indenting the surface of one piece below that of the other, and securing the pieces by iron straps. It is estimated that, to secure the best results from the above, the sum of the indents should be equal to the total depth of the beam.

Trussing.—This may be done within the depth of the beam, or it may extend beyond, and with wrought iron or cast. If the latter be used, it must be placed in such a manner that the stresses to which it may be subject, produce compression only. Cast iron may not economically be used to resist tension. In the example given on p. 177, Fig. 2, the beam, which is composed of two flitches, has been trussed by means of a tension rod passing down to the lower end of a vertical wooden strut provided with an iron face plate. The tension rod passes upward between the two flitches and through cast-iron shoes, specially prepared and provided with splayed backs, directly at right angles to the direction of the tie-rod. As has been previously stated, the trussing may be carried out within the depth of the beam itself, and, in that case, the face plate of the last example would be let into the under side of the beam, the bar passing under it.


Trussed Beams.
Fig 1.
6" × 6"
Struts
3½" × 6"
6" × 6"
⅛" Bolts
Fig.2
Two Flitches 11" × 4"
¾" Tie Rod
Fig.3.
1'-4"
Fig.4.
1'-4"
Span 2'-0"

A single beam may be trussed in a similar manner to the last, but in such a case the rods would pass down the outer faces, one on either side. Another example is shown on p. 194, the beam of the traveller being provided with two struts to afford additional support to the moving load. In order to receive the ends of the tension rods, the shoes are, upon both sides, provided with stout projecting ears, cast in the solid metal. Timbers may be trussed as shown at Fig. 1, page 177. This is the method usually employed in supporting the upper levels of gallery flooring, and in positions where parallel timbers are required both at the top and bottom, and where the increased depth is an advantage. Plain strutting, where possible, should always be preferred to cross bracing, as less labour is involved, and the full sectional area of the timber employed is effective. This is not the case where timbers cross each other in the same plane, the cutting or cross bracing reducing the effective area of the timbers joined by one half.

CHAPTER X.

TEMPORARY WORK, SHORING, AND CENTERING.

Timbering Excavations.—When earth has to be excavated for the construction of foundations, drainage, and other works, the sides need to be supported in a manner which will prevent them from falling in. The methods employed will vary greatly with the character of the soil and its condition. In moderately stiff soil, such as clay, and which has to be excavated only to the depth of 3 or 4 ft., vertical poling boards, from 8 in. to 10 in. wide, and from 2 in. to 3 in. thick, are placed at intervals of about three or four feet, and are supported by struts 4 in. by 4 in. or 5 in. by 5 in. These are kept in position by being firmly driven from the top and not from the sides (see Fig. 1, page 180). In loose, rubbly soil it will be advisable to support the sides with poling boards, closely placed, and in lengths of about 3 ft. Waling pieces are placed across the poling boards near their ends, and these are supported by the struts. Waling pieces require to be of stouter material than the poling boards, the thickness being largely controlled by the nature of the soil, and also by the spacing. The waling used in the excavations

Timbering Excavations

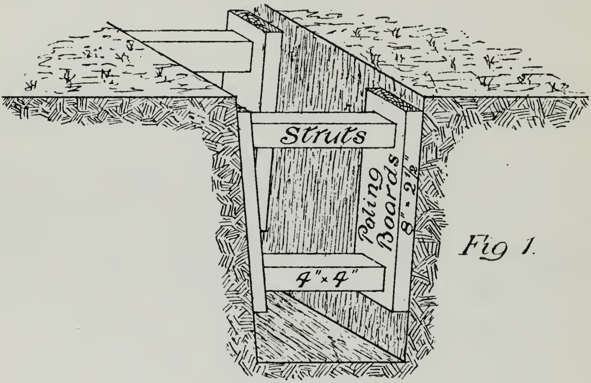


Fig 1.

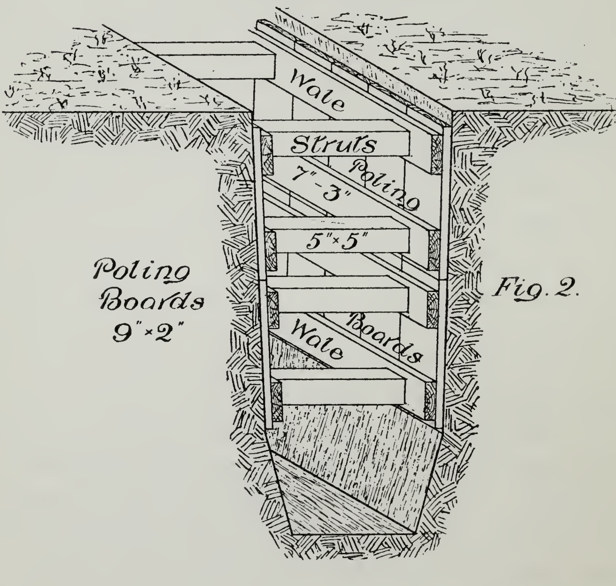


Fig. 2.

shown at Fig. 2, page 180, is of 7 in. by 3 in. material. In loose sandy soil, it will be found necessary to support the material by placing horizontal waling pieces directly against the soil, supporting these by vertical poling boards driven downwards, and, as the work proceeds, strutting them at regular intervals. In soft or waterlogged soil, such as river-bed work, it is necessary to use specially prepared sheeting, as shown in Fig. 95.

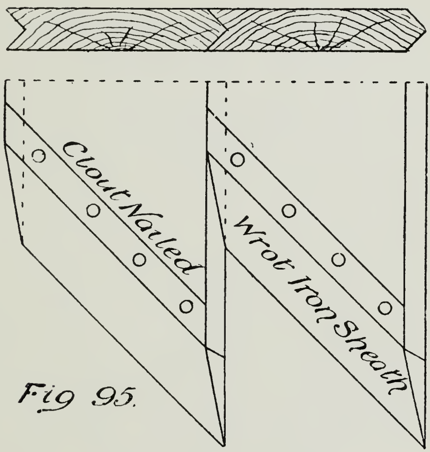


Fig 95.

This is of thin material, driven between stiffer timbers known as "guide piles." The sheeting is driven before excavating, the pointing of the ends of the boards (as shown in the figure) assisting to close the joints, and thus prevent, as far as possible, the escape of water. The joints are matched in the manner shown, so that pressure, being brought to bear upon any one board, may be distributed over a series.

Bearing Piles.—These are of whole timbers 10 or 15 in. square, and of a length varying with the

requirements. They are used for the purpose of creating foundations on soft and treacherous ground overlying a hard substratum. They are assisted in their passage through the soil by being pointed at the lower ends, and protected, as shown in Fig. 96, by cast-iron points, secured by wrought-iron straps and bolts. The heads are protected during the process of driving by wrought-iron rings.

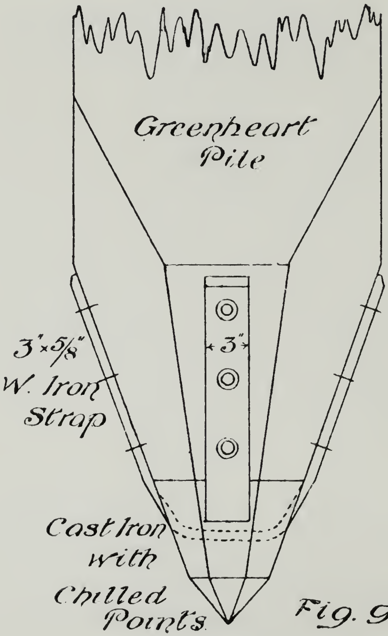


Fig. 96.

The pile driver is a vertical staging of wood-work, secured in its position by guy ropes, and having an engine, by means of which a large weight, called a "monkey," of from two to three cwt. is raised. The "monkey" is allowed to fall from a varying height,

regulated by the set required and by the resistance of the pile. The pile, by repeated blows from the "monkey," is driven to such a depth that, either by the friction of its sides against the soil, or by reaching a harder substance below, it is capable of affording the required bearing power.

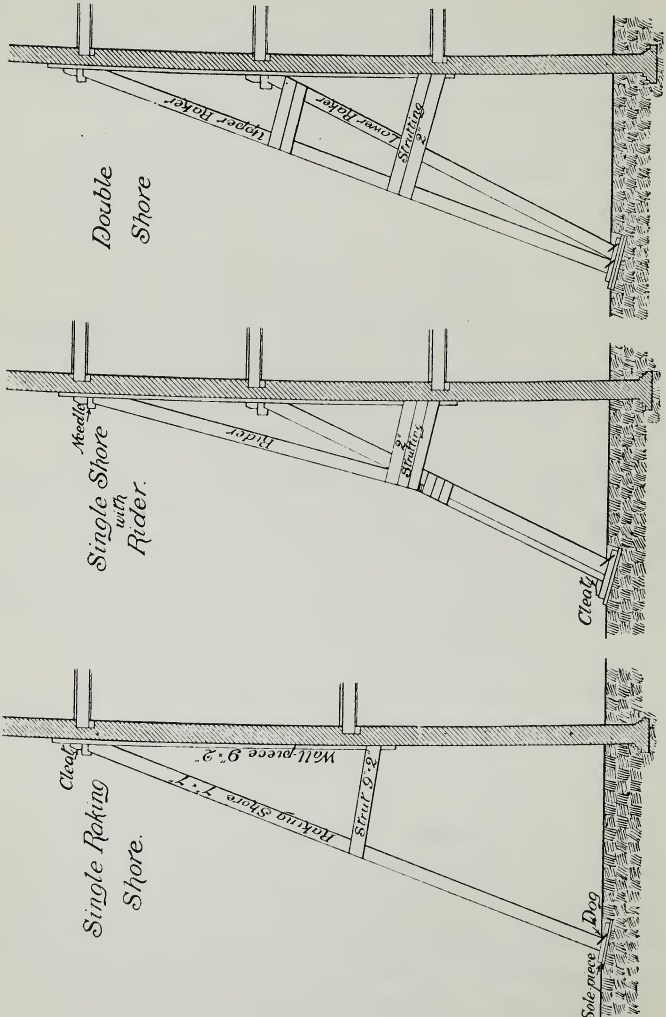
The resistance offered by piles may be found by the following formula:

$$L = \frac{WH}{8D}.$$

When L = safe load in cwts. (cut off at the ground),
D = set of pile by the last blow in inches,
H = height of the fall in inches,
W = weight of "monkey" in cwts.

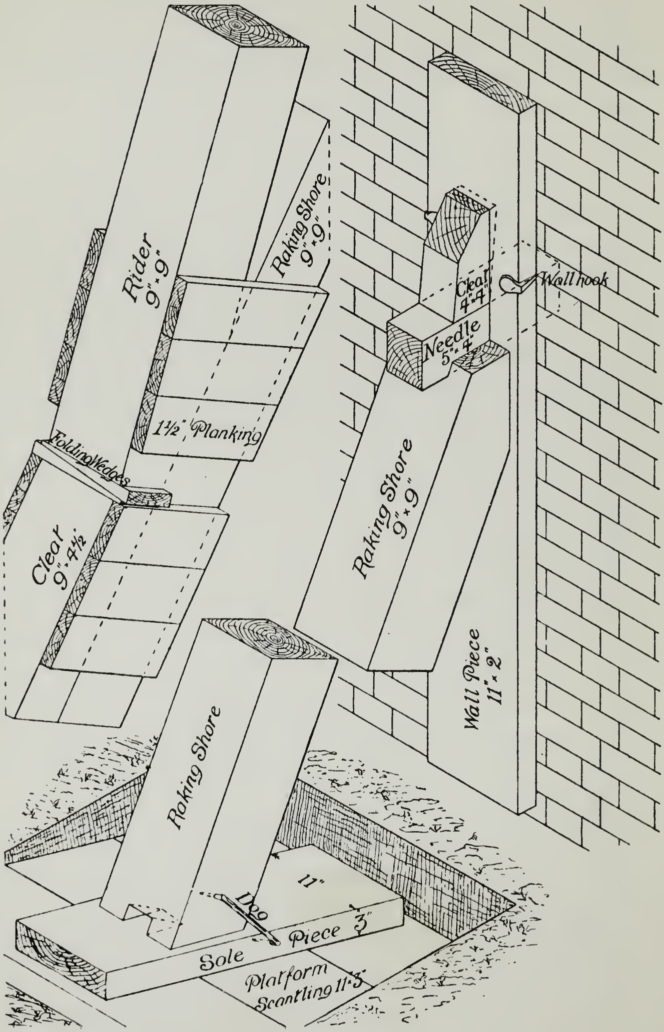
Shoring.—This is the term given to the methods adopted for temporarily supporting the walls of a building which shows signs of bulging, or of passing out of the perpendicular, or of supporting the upper portion of a wall during the process of underpinning, or altering the character of a portion of the building.

Raking Shores.—Those props or timbers which pass from the ground to the wall in an inclined position are termed "raking shores." They should be of whole timbers,—of the same dimensions, both in width and thickness. When a series of shores pass directly from the same platform to different points in the height of a wall, they are known as double or treble raking shores, according to the number of timbers so situated. It is the custom, under some conditions, to start a support from a point midway up the shore, and not directly from the ground; such support is known as a "rider."


Double Shore
Upper Raker
Lower Raker
Strutting 2"
Single Shore with Rider.
Needle
Rider
2" Strutting
Cleat
Single Raking Shore.
Cleat
Wall-piece 9"×2"
Raking Shore 7"×7"
Strut 9"×2"
Dog
Sole-piece

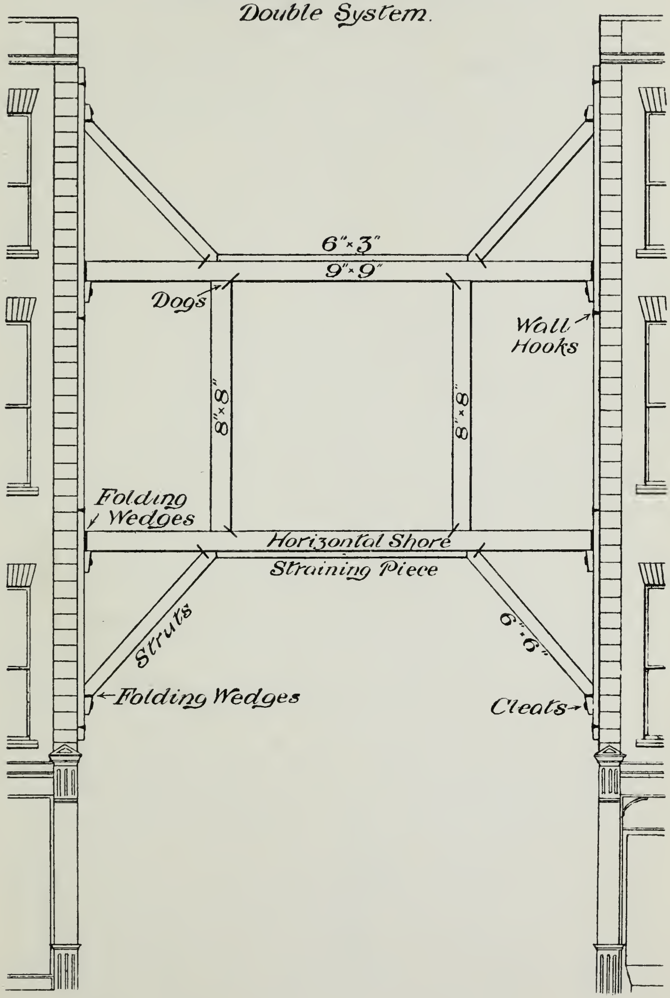
Illustrations of three varieties are given on page 184. In order to fix a shore, or system of shoring, a wall piece is first fixed to the wall, covering the portion inclined to bulge, and having mortised in it holes large enough for the "needle" to pass through. These needles are rectangular pieces of wood about 4 in. by 4 in. or 5 in. by 4 in., and about 18 in. long, which, after passing partially into the wall, are allowed to project about ten or twelve inches. Against these the head of the raking shore is placed, additional support having first been given by a cleat partially sunk into the wall piece immediately above the needle. The foot of the raking shore rests upon a platform composed of short ends of deals, about 3 ft. long, crossing and recrossing each other. Upon this a sole piece rests in a direction at right angles to the wall. The sole piece sometimes takes the place of a platform. In this case the material should be of a width and thickness equal to that of the shore itself. The raking shore is best adjusted by bringing the foot closer to the wall. This should be done with the aid of a handspike or crowbar. applying it as a lever of the second order. Jarring of the frame-work should be avoided so far as possible, as, in being communicated to the brickwork, the mortar joints are apt to be destroyed.

Riders are adjusted at either end by folding wedges, and are made secure either by a bonding of hoop-iron, or by planking. In the latter case the planking may be extended to the wall piece and made to serve the purpose of struts. Iron "dogs"—short pieces of $\frac{3}{4}$ in. round or square iron, with the ends pointed and turned through an angle of 90°—are then applied to keep the several parts in place. Shores, flying or raking, should


Rider
9"×9"
Raking Shore
9"×9"
1½" Planking
Folding Wedges
Cleat
9"×4½"
Cleat
4"×4"
Wall hook
Needle
5"×4"
Raking Shore
9"×9"
Wall Piece
11"×2"
Raking Shore
11"
Dog
3"
Sole Piece
Platform
Scantling 11×3

Horizontal or Flying Shores.

Double System.



be applied to walls in positions thoroughly well supported, such as the junctions of floors, or against the edges of other walls. Details of raking shores are shown on page 186.

Flying Shores.—These are horizontal shores passing across the space between two houses; and, as is the case with raking shores, as one, two, or three horizontal shores are used in the same trussing, so is the system known as single, double, or treble flying shores. Wall pieces and needles are used in this, as in the raking shores. The shores are cut a little short of the distance between the wall pieces, and rest temporarily upon cleats. They are then adjusted by means of folding wedges, additional support being rendered by strutting. The illustration given on page 187 is that of a double system of horizontal flying shores.

Dead Shores.—These are shown on page 189. The front wall of a ground floor has been removed for the insertion of a shop front. The upper floor windows are first strutted to prevent settlement, and then holes are drawn in the solid brickwork for the insertion of the needles; these must be in positions where they will not interfere with the progress of the work. Brickwork, to the extent of about 1 ft. 6 in. or 2 ft., on either side of the needles, may, with care, be left unsupported, or may be removed in steps upwards in the form of a rough arch. The needles are supported at either end by upright timbers known as "dead shores," resting upon "fenders" or "sleepers," and, as will be seen in the section on page 189, the shores may be made the means of supporting the floors that may intervene. The floor is here carried upon a long plate of 11 in. by 3 in., supported by the shorter shores,

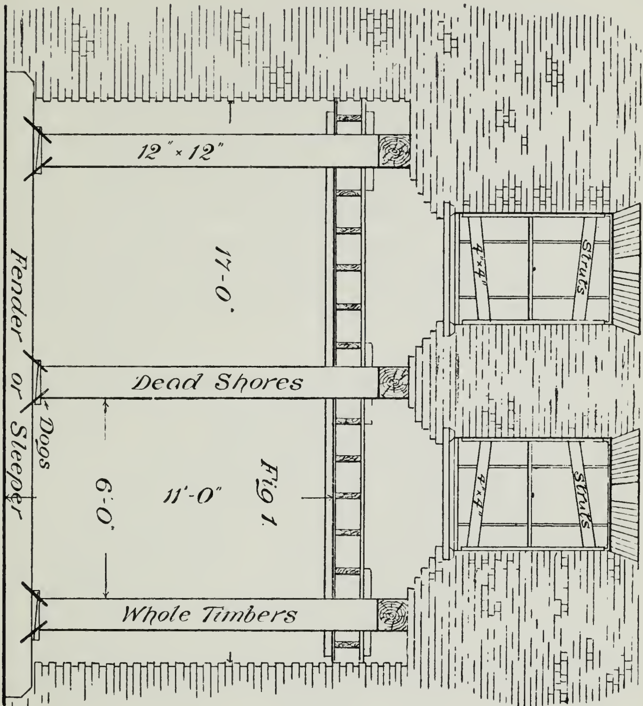

12" × 12"
17-0"
Dead Shores
Whole Timbers
6'-0"
11'-0"
Fender or Sleeper
Dogs
4"×4"
Struts
4"×4"
Struts

Fig 1.

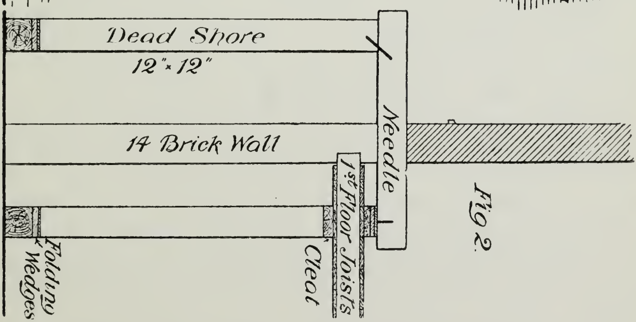

Dead Shore
12"×12"
14 Brick Wall
Needle
1st Floor Joists
Folding Wedges
Cleat

Fig 2.

and adjusted by folding wedges at the base, the difference between the top surface of the floor and the underside of the needle being taken up with short cleats or plates resting on at least three or four joists, and this again adjusted by means of folding wedges. Sufficient space must be left between the shores and the wall on either side to carry on the progress of the work. The joints are all plain-butted, and are secured in position by iron "dogs." Upon removing supports of this kind, it is always advisable to do so by degrees, so that all new work may take up its bearing gradually, and without fracture.

Centering.—A "centre" is a rough, temporary platform of wood, upon which arches are sprung. It should, in the outline of its elevation, be of the exact form of the archway. It is composed of two or more cheeks or ribs firmly secured together, whilst upon their upper edges pieces, called "laggings," are fixed, ranging in size from small battens to heavy planking according to the nature of the work. It is upon the laggings the voussoirs or arch stones rest during the building of the arch. In order to apply the plumb-rule and straightedge, it is necessary to keep the laggings a little short of the face of the work, $\frac{1}{2}$ in. upon each side being sufficient in small work.

As the "centre" takes the weight of the voussoirs until the keystone has been placed in position and the centre "struck," great care is required in deciding upon the correct positions for the struts, so as to economically carry the superincumbent weight with safety.

It has been found by experience and investigation that arch stones do not begin to slide upon their beds

until the joints are inclined at angles of about 30°, varying according to the material, the condition of its surface, and also to the nature of the cementing material employed. It is therefore obvious that centres are not required to lend support to the voussoirs until the bed joints of the latter have reached what is known as the "angle of repose" of that material. This tendency goes on increasing with the angle of the bed joints until a perpendicular line through the centre of gravity of any voussoir falls without its base, in which case the whole weight of the stone has to be borne by the centre.

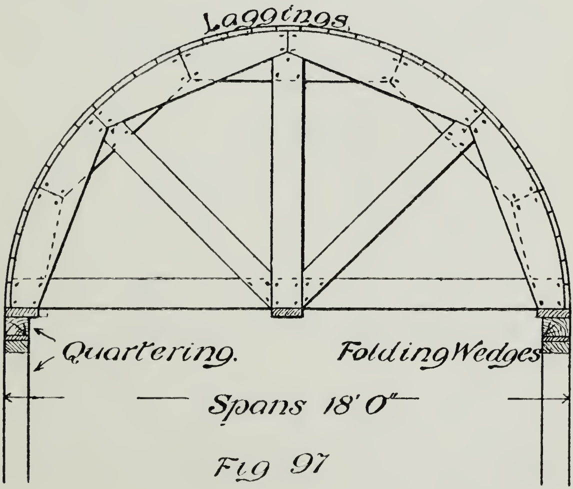
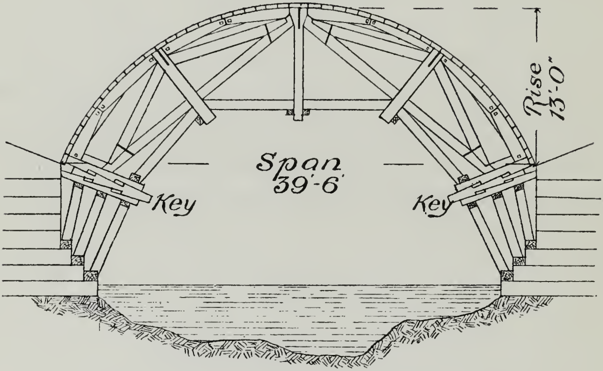


Fig 97

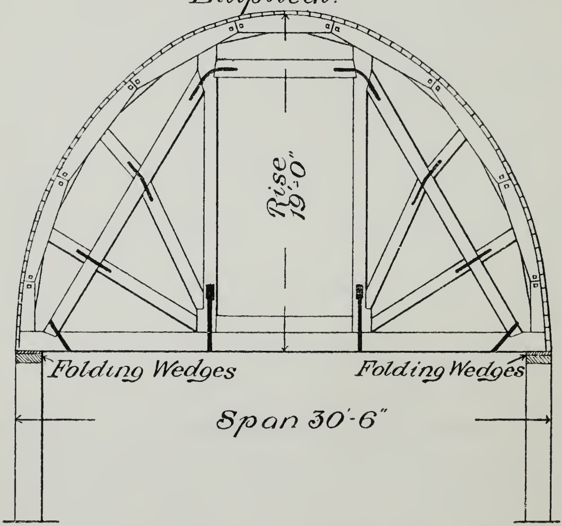
Fig. 97 is an example of centering for a semicircular arch, the span of which is 18 ft. Up to this span ordinary planking ribs may be used. These may be nailed together with butt joints, and in such a manner that they break line with each other.

Centres.

Segmental.



Elliptical.

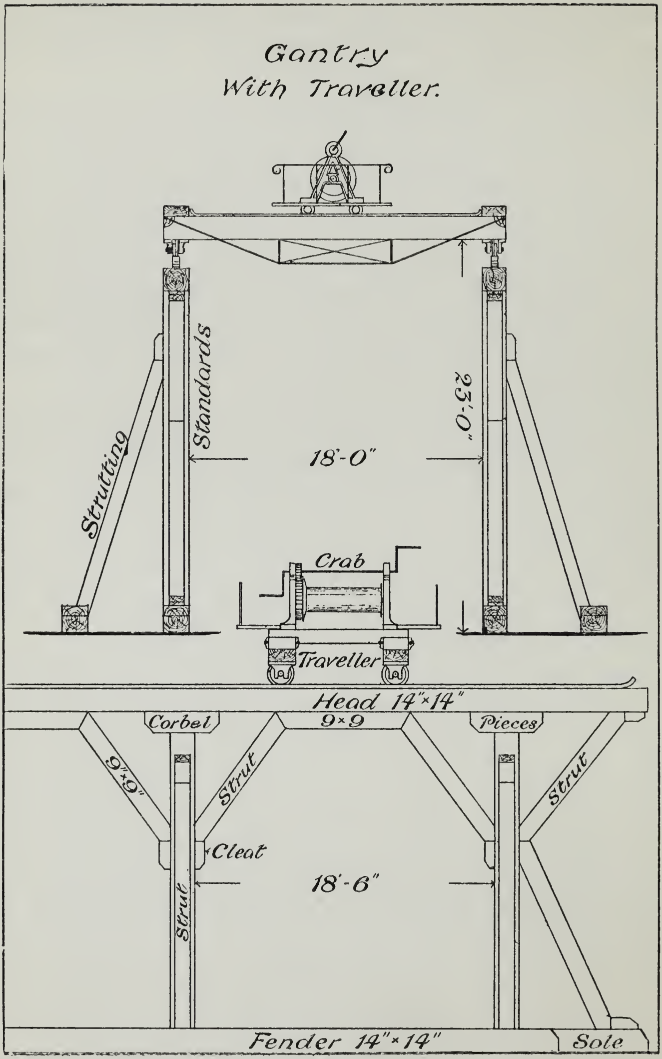


When arches exceed the span given in the last example, the centres need to be trussed either with small king-posts or with queen-posts. Two such examples are shown on page 192.

Striking or Easing Centres.—After the keystone has been placed in position, and before the mortar or cementing material has had time to set, the centre should be eased, or allowed to drop slightly from its position, so that the voussoirs may be able to take up their own bearing. This should be accomplished by degrees and with great care, avoiding all unnecessary jarring or unequal settlement, or fracture may occur and the work be rendered insecure.

For small work the striking is carried out by easing the folding wedges inserted between the centre and its supports; but in the larger varieties tapered and stepped cotters or keys are employed, as shown on page 192. These are allowed to project until the arch is completed, and then, by driving them back by degrees, the "centre" drops from its position.

Gantries.—For the purpose of lifting heavy masonry or other work, a gantry, similar to that shown on page 194, is constructed, the standards passing down on either side of the work. These are usually arranged with a traveller and hoisting gear, so that material may be lifted from any position of the work. In some important work the movement of the traveller and the hoisting gear is controlled from one point, usually at ground level.


Gantry
With Traveller.
Strutting
Standards
18'-0"
23'-0"
Crab
Traveller
Head 14"×14"
Corbel
9×9
Pieces
9"×9"
Strut
Strut
Cleat
18'-6"
Strut
Fender 14"×14"
Sole

CHAPTER XI.

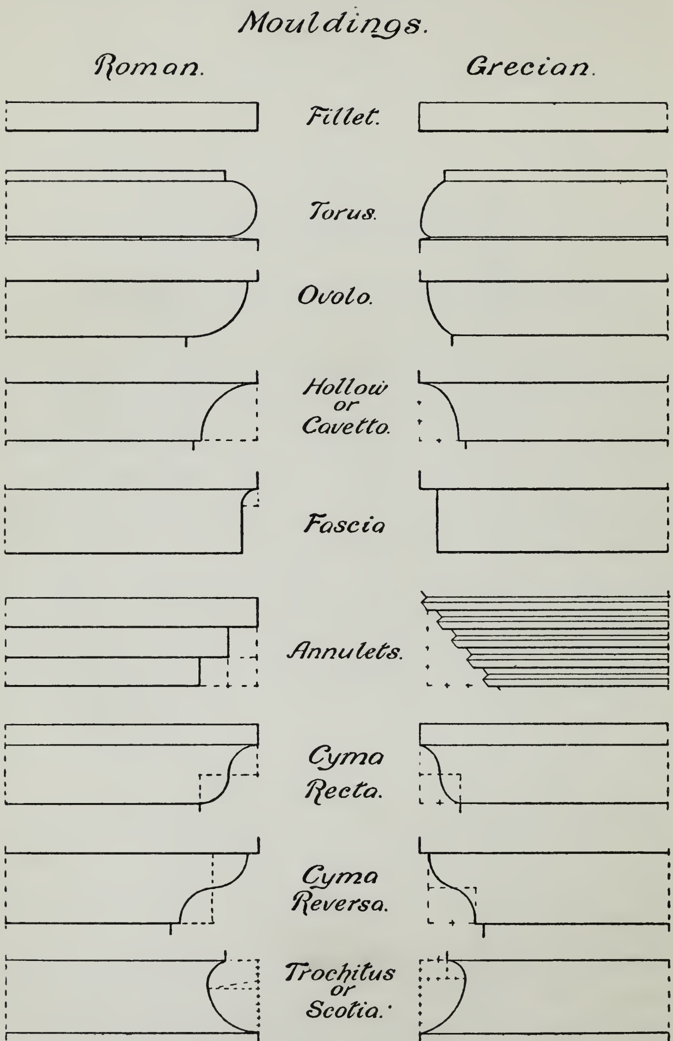
MOULDINGS AND CIRCULAR WORK.

THE mouldings which are used at the present day are mainly of Grecian and Roman origin. They are shown separately on page 196, whilst a combination of some of them will be seen in the cornice, frieze, and architrave on page 199. Speaking generally, the mouldings of both types will be found to be of the same combinations, but with this distinction—the Roman mouldings are of circular outline, whilst the Grecian mouldings are elliptic, or of curves, other than the circle.

Fillet.—This is a flat, narrow band alike both in the Roman and Grecian. It is used principally to divide the combinations of the other mouldings, and caps the cyma recta and cyma reversa.

Torus.—This is the bead as known at the present time. It is commonly used as a plinth or base moulding, and gives the appearance of strength and support.

Ovolo.—This is another of the mouldings which convey the impression of support, and with the cyma reversa and scotia—other mouldings designed for the same purpose—are usually placed in cornices or capping moulds.


Mouldings.
Roman.
Grecian.
Fillet.
Torus.
Ovolo.
Hollow or Cavetto.
Fascia
Annulets.
Cyma Recta.
Cyma Reversa.
Trochitus or Scotia.

Hollow or Cavetto.—This, with the two following, viz., annulets and cyma recta, are intended to convey an impression of shade, whilst the fascia gives the impression of light.

Astragal.—This is a projecting semicircular or bead-shaped moulding, shown in its various forms at Figs. 98 to 103.

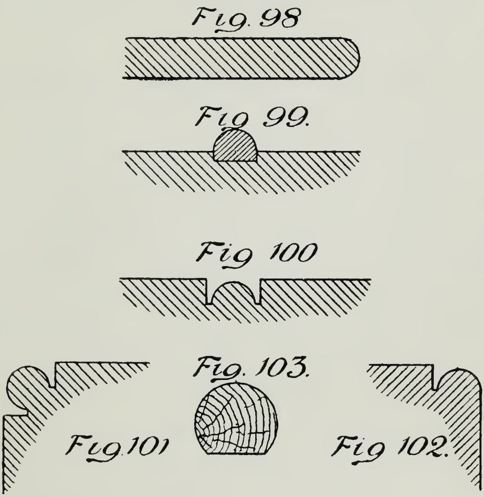


Fig. 98 is a representation of the true astragal as a horizontal band; when situated as a vertical moulding, as Fig. 99, it is known as a cocked bead. When sunk below the surface, as at Fig. 100, it is known as a double quirked bead. Fig. 101 is a representation of a returned bead, whilst at Fig. 102 is seen the ordinary or single quirked bead. The latter stuck upon the edge of matched boards, or boards placed with their edges in contact with one another, has the

effect shown in Fig. 100, and counteracts the unsightly appearance of an open joint. Fig. 103 represents the angle or staff bead. It is in section of the form of a segment of a circle larger than the semicircle. It is fixed as a protection at the angle of plastered walls, the flattened surface affording a key for the plaster.

Hollow and Astragal.—This, as shown on page 201, is a combination of hollow and round, with a listel or fillet between.

Enlargement and Diminution of Mouldings.—The example given is that of a combination of cornice, frieze, and architrave (Fig. 1, page 199). It is required to reduce its projection from *GH* to *IJ*, and its height from *AB* to *CD*. Taking the projection *GH* first. Draw *IJ* of the required length parallel to and at a convenient distance from *GH*. Join *HJ* and *GI*, producing them to meet in *K*. From all important points in the projection of the moulding, drop perpendiculars to *GH*. From the feet of the perpendiculars draw lines converging to *K* and intersecting *IJ*. *IJ* will then be divided proportionately to *GH*, and will represent the diminished projection of the moulding. For the diminished height repeat the process at *AB* (Fig. 1), drawing *CD* of the required height parallel to and at a convenient distance from *AB*.

If the height and overhanging projection are to be reduced in strict proportion, then the triangles *GHK* and *ABN* must have their perpendicular heights divided by *IJ* and *CD* in the same ratio. This is perhaps best accomplished by making the two triangles similar, and dividing the similar sides proportionately.

Mouldings may be enlarged by placing the line

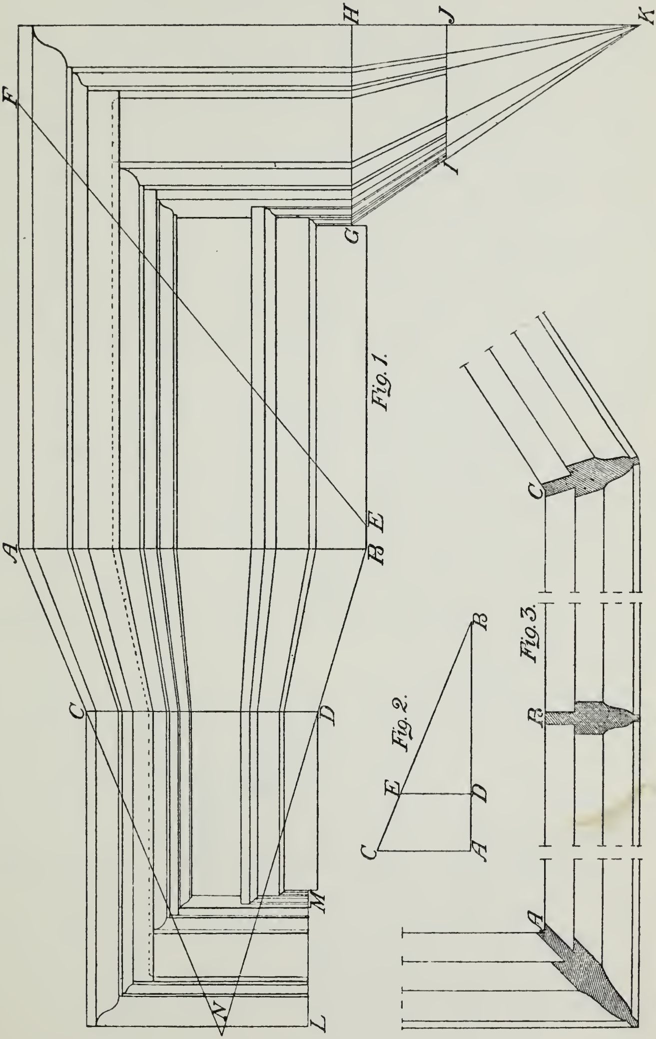


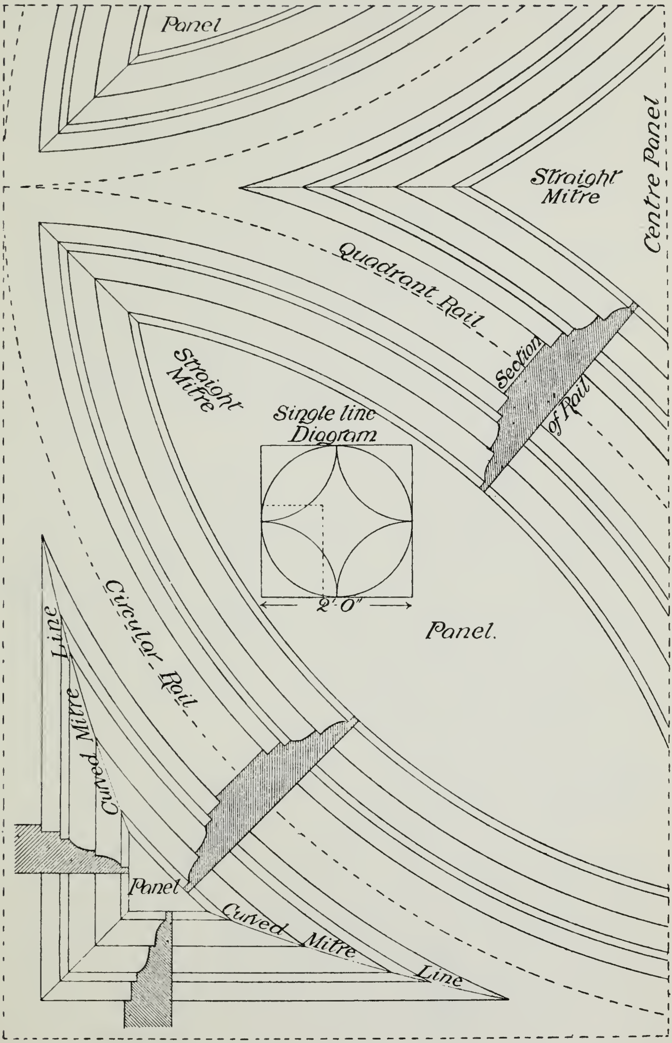
Fig. 1.
Fig. 2.
Fig. 3.

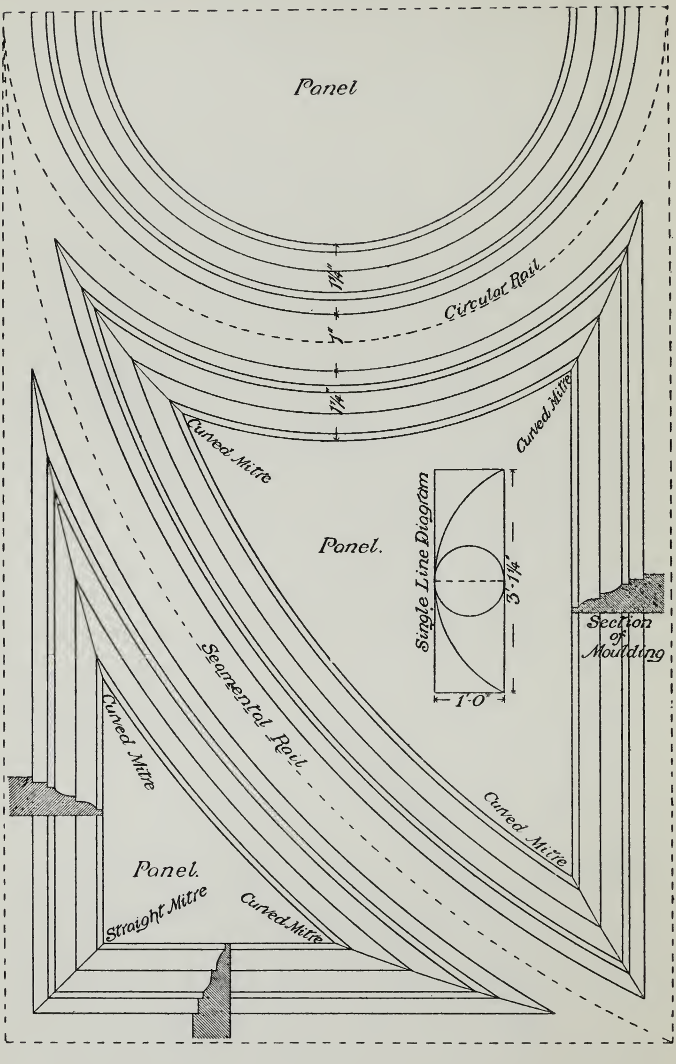
representing the increased height obliquely across the moulding, as at *EF*, the increased heights of each member being represented by that portion of the oblique line crossing the member. The increased overhanging projection is obtained in a similar manner by placing the line representing that distance obliquely across the perpendiculars over *GH*. The enlargements may also be found by triangles similar to the method of diminishing. In that case, the lines *IJ* and *CD* would be replaced by the increased distances, and the positions of the apices of the triangles *K* and *N* would be reversed, and placed on the opposite sides of the bases *GH* and *AB*.

The term "similar" has been mentioned with reference to the triangles used in the enlargement and diminution of mouldings. In order that triangles may be similar, it is only required that they shall have their several angles equal each to each, then the sides about their equal angles are proportional. Fig. 2, page 199, is a representation of two similar triangles, *CBA* and *EBD*.

Raking Mouldings.—These are shown at Fig. 3, page 199, the sections *A* and *C* being the raking sections of the bar *B*. The student will readily understand the method of obtaining them from the figure, the thickness being in each member the same.

Intersections of Curved Mouldings.—The illustrations furnished on pages 201 and 202 are given to show how the mitres of curved mouldings of panelled soffits are obtained. A single line diagram of a separate scheme has been shown in each case, and, to avoid needless repetition, a portion only has been enlarged. The enlarged portion of each diagram has been repre-


Panel
Straight Mitre
Centre Panel
Quadrant Rail
Section of Rail
Straight Mitre
Single line Diagram
2'0"
Panel.
Circular Rail
Line
Curved Mitre
Panel
Curved Mitre Line


Panel
1¼"
1"
1¼"
Circular Rail
Curved Mitre
Curved Mitre
Panel.
Single Line Diagram
3'·1¼"
1'·0"
Section
of
Moulding
Segmental Rail
Curved Mitre
Curved Mitre
Panel.
Straight Mitre
Curved Mitre

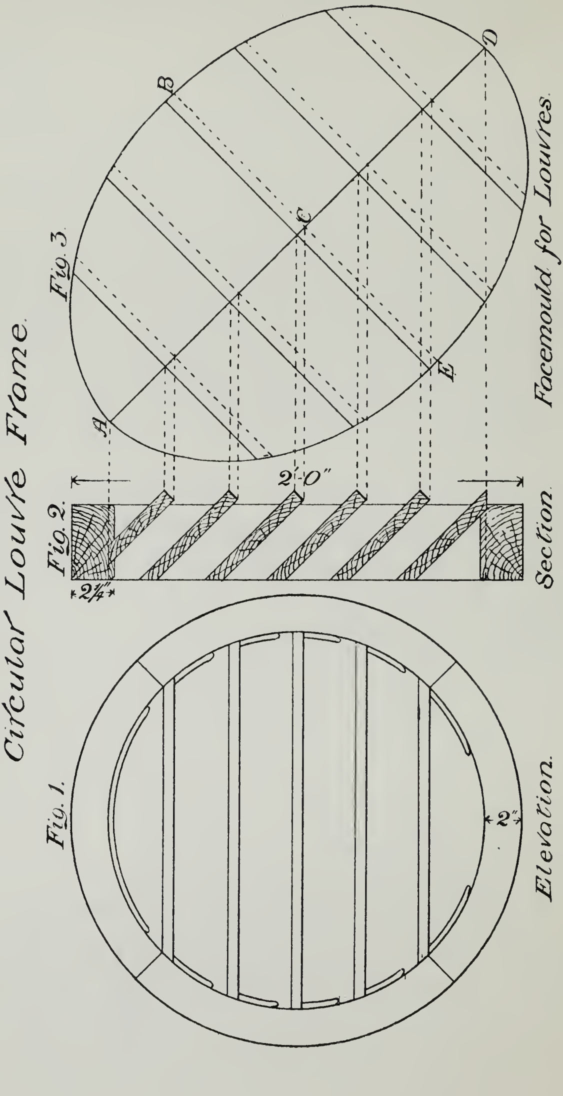
sented by the dotted lines at the centre of each rail. The following is a summary of the results obtained:

Mouldings Intersecting.	Mitre Obtained.
Two straight mouldings (any position), -	Straight.
Two curved mouldings of equal radii (internally or externally), - -	Straight.
Two curved mouldings of equal radii (internal with external), - -	Curved.
Curved mouldings with unequal radii (internal, external, or combined), -	Curved.
Curved mouldings with straight (internally or externally and acute or obtuse), - - - - -	Curved.

In mouldings of curved outline and with but few members, supplementary marginal lines must be adopted, and through their intersections a fair curve representing the mitre line may be drawn.

Circular Louvre Frames.—These are ventilating frames fixed in the walls of stables and other buildings where air is required without light. The fixing of the louvre boards in the manner shown on page 204 prevents the driving rain from passing to the interior, whilst currents of fresh air are directed upwards towards the ceiling, and there diffused.

The method of obtaining the outline of the louvres will readily be seen when it is understood that they terminate upon a cylindrical surface, the diameter of which is equal to the distance between the quirks of the beads (see page 204). By producing these lines, and by drawing the line *ACD* parallel to the sloping sides of the louvres, and intersecting the lines produced

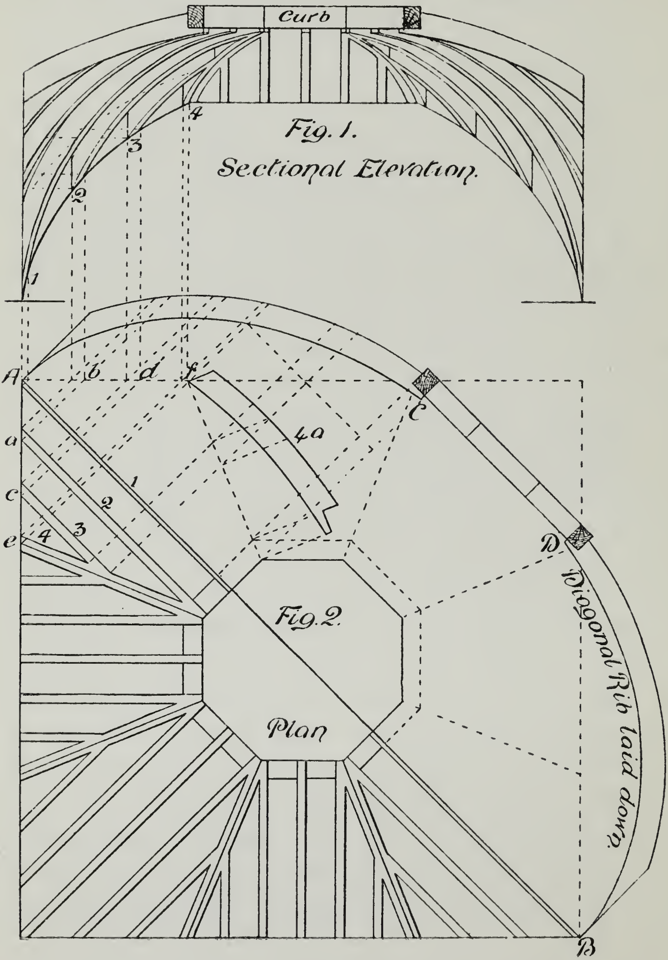

Circular Louvre Frame.
Fig. 1.
Elevation.
2"
Fig. 2.
Section.
2¼"
2'-0"
Fig. 3.
Facemould for Louvres.
A
B
C
D
E

in *A* and *D*, the major axis of the elliptical section of the cylinder is obtained. The minor axis *ECB* is made equal to the diameter of the cylinder; the axes bisecting each other at right angles, the outline of the curve may be drawn. In order to find the true shape of any louvre, project its extremities from the section of the frame to the major axis. If, from these points, lines be drawn at right angles to the major axis to meet the curve, the outline of the surface of the louvre will be obtained. A pattern will be required for each side, but both may be obtained by the same process.

Pendentives.—The term "pendentive" is analogous to that of "spandrel," and it will be necessary to thoroughly understand the latter before a proper conception of the former may be obtained. A spandrel is the irregular triangular surface intercepted between the extrados of an arch and an imaginary rectangle surrounding it. Where two arches are placed in continuation, the whole of the triangular surface included below an imaginary horizontal line joining the crowns and the outline or extrados of the arch on either side is termed the "spandrel." The term "spandrel" is applied to plane surfaces only. When the surface is curved and intersected by vertical or horizontal planes, the portion intercepted between such planes is known as a "pendentive." The figures given on page 206 will serve, not only to illustrate the meaning of the term "pendentive," but to show how the curves of the ribs are obtained. In this case, when the main rib *AC* or *DB* is laid down, all other parallel ribs may be taken from them.

To find the Curve of the Ribs.—Having drawn the plan, and laid down the main rib *ACDB*, with section

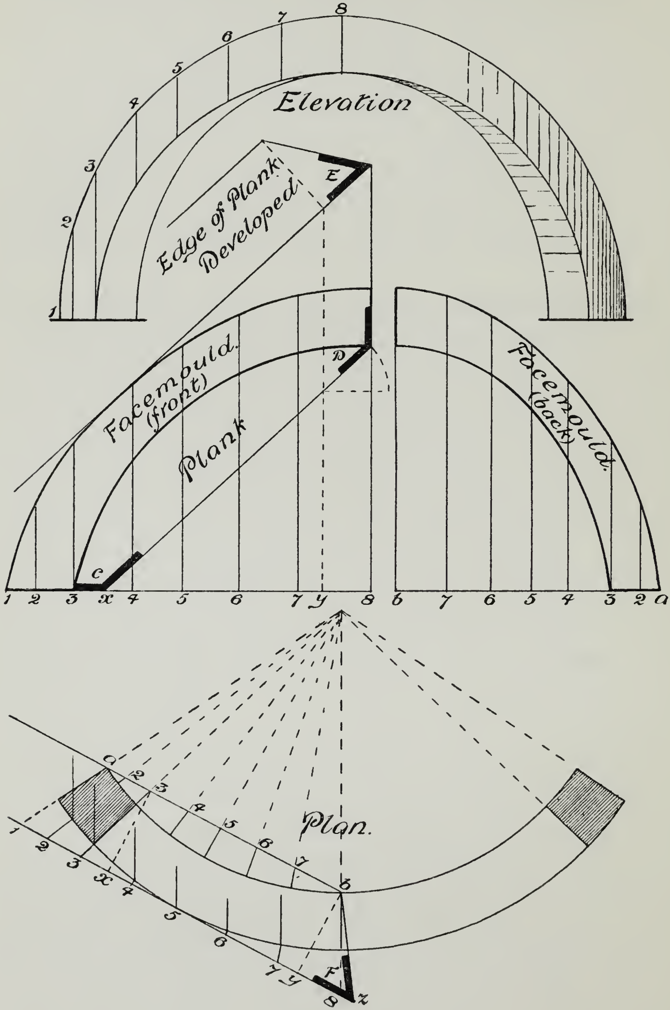
Pendentive
Intersection of Elliptic with Octagonal.



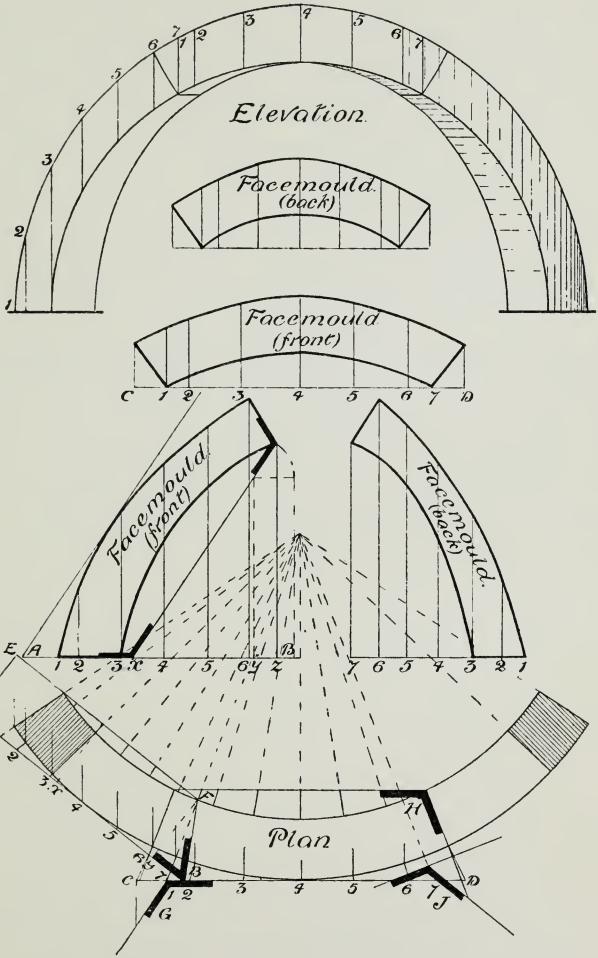
of octagonal curb, trace the dotted lines from *a*, *c*, *e*, etc. (Fig. 1), crossing the diagonal *AB* at right angles and intersecting the main rib. The portions intercepted between the dotted lines from each rib will represent the face-mould of that portion. The face-mould for the angle rib is represented at 4*a*, and is obtained by a fresh development of the upper portion of the rib upon the plan of the rib at *f*. The heights of the points 1, 2, 3, and 4, in the sectional elevation, are also obtained from the development of the large rib.

Circle on Circle.—Work that, in plan and elevation, has a circular outline is known as "circle on circle" work. In order to describe the methods employed to obtain the lines, the circular headed door frame has been selected. Two examples will be explained, viz., the head divided in two and also in three parts. The example given on page 208 is that of the head divided in two. Having drawn the plan and elevation, draw the chord *ab* in plan, and the tangent *xy* parallel to *ab*. These lines represent the plans of the back and front surfaces of the required plank, and their distance apart, the thickness. Draw the radiating dotted lines intersecting *ab* and *xy* in points 1, 2, 3, etc. Project the points upwards, to the front surface of the frame in elevation, and draw the vertical lines 2, 3, 4, 5, etc. The heights of the upper and lower extremities of these lines upon the front and back will represent the heights of similar ordinates upon the face-mould. Transfer the lines *xy* and *ab* with their numbers to a convenient position and set up ordinates, cutting them off in length equal to those in elevation. Trace a fair curve through the points on the ordinates, and the face-mould

Circle on Circle.



Circle on Circle.



is obtained. It will be noticed that the line $3x$ has been taken perpendicular to the line ab; x therefore represents the internal edge of the plank at the lower end. Join D with x, and the edge of the plank is determined. The other edge of the plank is drawn tangent to the face-mould and parallel to the first edge, the bevels at the ends being represented at C and D. If the edge of the plank above b,y be developed, the bevel at that end will be found. This is shown at E and F. At the other end a square is used. In the example shown on page 209, the head of the frame is divided into three, and the method of obtaining the face-mould is similar in each case. The student should remember that the joints between the three are butted, and are normal to the curve at that point. The bevel at G is applied to the vertical surface of the top portion, whilst the bevel at H belongs to the top and bottom edge. The bevel at J is applied to the ends in a manner somewhat similar to a square.

CHAPTER XII.

TIMBER: ITS GROWTH, TREATMENT, AND PRESERVATION; VARIETIES AND THEIR PECULIARITIES, USES, AND DEFECTS.

Growth.—Upon examination of a transverse section of one of the soft-wood trees, such as the firs or pines, a series of concentric and more or less regular circles will be found, composed of light and dark material. With the exogens or outward growers, these rings or layers are produced by the ascending sap in the spring, forming what is known as spring-wood. After being exposed upon the leaf to the action of the sun, the sap is decomposed, and in its altered condition returns by way of the trunk, depositing another layer, known as autumn-wood, differing slightly in colour, and thus creating a line of demarkation between the spring-wood of one year's growth and that of the next.

In tropical climates this motion of the sap takes place in the rainy seasons, and the annual rings are not so strongly marked. The annual rings are composed of a number of small cells, which in some timbers can only be distinguished by the aid of a microscope, whilst in the coarser grained timbers, such as that of the oak, they may be seen with the naked

Fig. 1.

Fig. 2.

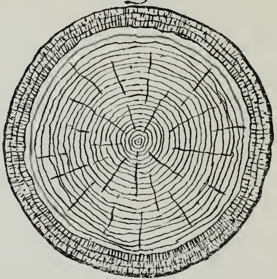


Fig. 3.

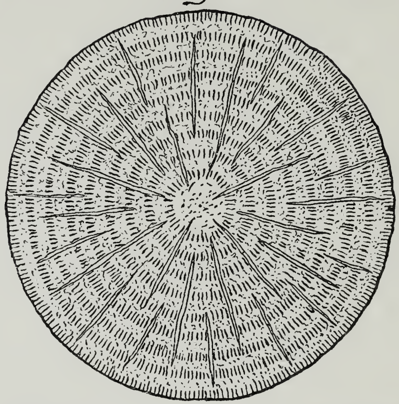


Fig. 4.

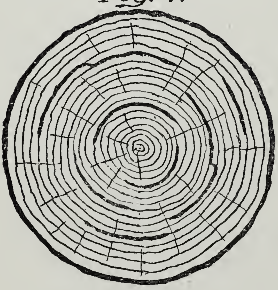
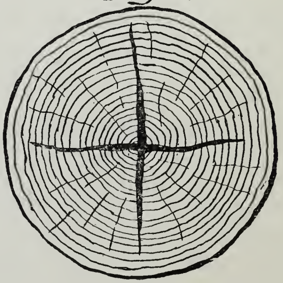


Fig. 5.



eye. Communication of the sap is carried on between the annual rings by cells, contained in radial planes, and known as medullary rays. These are found in all timbers, but are more strongly marked in the oak, beech, and plane trees, and are known by the joiner as the felt, silver grain, or clash, and are illustrated by the radial lines in Fig. 3, page 212. The formation of the growth externally causes the heart of the tree each year to become more dense. The student will notice this for himself; the wood nearest the heart offers more resistance to the tools than that more remote. Upon close examination of a log of timber, there will be found, besides the annual rings, two distinct classes of wood, in some cases differing in colour, and usually separated by one distinct ring. Two such logs are shown at Figs. 1 and 2, page 212. These different classes of wood are known by the names of duramen and alburnum. The former is the heart or perfect wood, whilst the latter is the sapwood. This latter variety is found upon the outside of the trunk, but upon the growth of new wood exteriorly, the older portion of sapwood becomes indurated and changes its state to that of duramen or heartwood.

With the younger trees the sapwood forms by far the greater part of the trunk, but as the tree reaches maturity, the perfect wood or duramen increases and the sapwood becomes less in proportion. Fig. 1, page 212, represents a section of the trunk of a tree of immature growth, with the sapwood forming by far the greater portion of the section, whilst Fig. 2 is a representation of the section of a trunk of mature growth, the sapwood forming but a small portion of the section.

Felling.—This is the operation of cutting down the tree previous to its conversion into timber. From the foregoing remarks it may be inferred that a tree, in order to be fit for the builder, should have arrived at maturity, or, if not, it will be found to contain a large quantity of alburnum or sapwood, which is deficient in strength and durability. The mature age of a tree varies considerably, according to the class to which it belongs, but ranges from 60 to 150 years. A tree that has passed maturity will lack a full growth of foliage at the top. At the appearance of such signs, the tree should be felled in order to save its wood. Another important point to consider is with regard to the seasons. It is advisable that a tree should be felled when the sap is at rest; this, in temperate climates, is at midsummer and midwinter; but the latter is to be preferred, as at that period the trunk contains less of its juices, and is not so liable to fracture in drying. For the same reason, in tropical climates, the dry seasons are the best for felling purposes.

Seasoning.—This is the process of extracting from the timber its moisture and sap. In the resinous varieties it is advisable to roughly square the log as soon as it is felled. This not only facilitates the drying process, but prevents the wood from splitting. The student will understand, from the relative dimensions of the circumference and diameter, how it is that whole timbers "shake" to such an extent in drying. In addition to this, it is found that timbers shrink considerably more in the direction of the ring than across. This is shown at Fig 3, page 224, and, although exaggerated, points out the direction in which the greatest change takes place.

No seasoning process is equal to the natural process of air-drying; by it the timber not only retains its natural elasticity, but the process of desiccation is brought about without that amount of warping, twisting, and splitting so common to other methods. It is carried on in open sheds by stacking and stripping the timber upon elevated platforms, so constructed that they are true in plane, otherwise a permanent twist may be given to the material so stacked. The strips used vary from one to three inches in thickness, are placed at regular distances along the stack, and in strictly vertical lines, so that no cross strain is put upon the material. Timber should not be subjected to direct sunlight. Where timber sheds are erected in exposed positions, it is advisable to cover the sides with louvre boarding, so that, whilst the air would have free access, the rain and direct sunlight would be prevented from striking the timber. The time required by the process varies with the class of timber, its sizes, and the condition when received. Fir may be instanced, as taking half the time occupied by oak.

Oak, 24 in. sq., will occupy about two years.
Oak, 7 in. or 8 in. sq., will occupy about six months.
Other scantling in like proportion.

The stacking of large quantities of timber by the builder represents a great expense, and is looked upon as so much money lying idle, and can therefore only be carried out by firms heavily financed.

Water Seasoning consists of wholly immersing the timber in "ponds"—convenient places near large timber yards, usually close to the banks of navigable rivers. This process is carried on for about three

weeks, in which time a large part of the sap is washed out. The material is then dried in stacks as above.

Hot-Air Process of Seasoning.—This is a process only applicable to small timbers, as wood, being a poor conductor of heat, a small portion only of its depth is affected by it. It is carried on in chambers heated by steam (usually the spent steam from the engine) passing through a series of 3-in. or 4-in. pipes below the floor, the timber being carefully stacked so as to allow of the free access of heated air and evaporation of the moisture, and at the same time to prevent warping and twisting. Condensing tubes, through which cold water passes, should be placed at intervals around the chamber, so that the moisture, as it evaporates from the timber, may condense upon the surface of the pipes and find its way by channels to the exterior.

Smoking.—This is known as "M'Neile's" process, and is reputed to produce good results. The operation, like the previous one, is carried out by stacking in a brick chamber, but in this case the products of combustion are allowed to enter the chamber, the atmosphere of which is kept moist by the evaporation of water contained in a tank situated below the timbers but above the fire.

In all processes of desiccation care should be exercised to apply the heat gently, as by a rapid process the timber is injured by splitting.

Steaming.—This is a process by which the wood is subjected to the action of steam, and is considered to be effectual with any sized timbers. In this process the timber is stacked in wooden tanks, but stripping is necessary only to allow of a free passage of the steam,

as no warping or twisting takes places. The time occupied is calculated at the rate of one hour for every inch in thickness.

PRESERVATION.

In order to prevent, as far as possible, the decay of timber, several methods have been brought forward, each tending to a greater or less extent to bring about the desired result; they are as follows.

Painting.—This is a process of covering the surface with sublimate of lead, or in work subjected to sulphur fumes, zinc white. These are thinly spread over the work by means of a brush, the vehicle used being linseed oil with a small addition of driers.

With all coating methods the material should be thoroughly dry before the application of the preservative, otherwise the moisture within the material would be prevented from escaping, and dry rot would ensue.

Tarring.—When the work is of a rough character and out of doors, covering the work with gas tar is often resorted to.

In either of the above processes two, three, and four coats are often applied to make it effectual.

Sanding.—This is a process of covering the surface with sand. The work is first coated with stiff paint and the sand sprinkled over it, afterwards dusting off the superfluous sand and repeating, finally coating the surface with a paint to produce the desired colour. This has the effect of making the work appear like stone.

The sand should be clean and free from all loamy or earthy matter.

Charring the ends of posts previous to embedding them in the ground has been found to have a beneficial effect, especially in soils inclined to be wet. The effect of carbonization is to render the material so treated proof against decomposition, but, like all other coating processes, the interior must be either deprived of its sap, or have its condition so changed that it is not likely to become decomposed. Several methods have been tried, in order to render immutable the decomposable elements, amongst them being the following: Abel's, Bethell's, Boucherie's, Burnett's, Gardner's, Kyan's, Margary's, and Payne's.

The process of treatment recommended by Sir F. Abel is a three-coat one, the first coat of which consists of a dilute solution of silicate of soda, containing one of a saturated solution of the same to four of water. The second coat consists of a creamy solution of fat or pure lime; whilst the third consists of a similar solution to the first, diluted to the extent of one of the saturated solution to two of water. These solutions are applied to the smooth surface of the work by means of a brush, care being taken that the silicate of soda solution is dry before the application of the lime. The effect of this process is to increase the lasting properties of the wood, and to render it uninflammable.

Bethell's process is one of creosoting, and although it renders the timbers highly inflammable and of objectionable smell, it is the most effective and popular process now in use, and is proof against the attacks of animal life. The process consists of piling the timber in wrought-iron tanks, creating a vacuum within the same, and then subjecting the timber to a

solution of creosote at a temperature of 120°, and at a pressure of about 150 lbs. per sq. in. Specifications for creosoting should state the quantity per cubic foot to be injected. This ranges from 8 to 12 lbs. per cubic foot, according to the class of work for which the material is to be used.

Sir William Burnett's process is somewhat similar to the above, but in this case a metallic salt is used. The solution of the salt (1 lb. of chloride of zinc to 6 or 7 gallons of water) is forced into the pores of the wood under a pressure of 150 lbs. per sq. in. The advantage of the process is that the material appears to be more thoroughly impregnated than in the former method. There is an absence of smell. The material is rendered uninflammable, whilst the poisonous nature of the salts renders it proof against the attack of insects. The material (chloride of zinc) is soluble in water, and therefore, to a slight extent at least, is liable to be washed out. Experience has proved, however, that a sufficient quantity is retained for all practical purposes.

M. Boucherie's process is one of impregnating the material, by slight pressure, with a solution composed of 1 lb. of sulphate of copper to 12 gallons of water. The newly-cut end of the timber is provided with a collar or washer of leather or felt, whilst a disc of wood is made fast to the end of the timber by means of a screw through the centre, and in such a way that the felt washer intervenes, creating a small space over the end of the timber. This chamber is then connected by means of a rubber tube to a tank containing the sulphate of copper solution. The tank is placed at a height of about 15 or 20 feet, so that

a "head of pressure" is created. The solution, entering the pores of the wood, forces the sap out and takes its place. It takes but a few hours to complete the process, and it is said the material is at once ready for use. The completion of the process is indicated by the application of prussiate of potash to the other end of the material; a complete passage of the salt is marked by a brown stain.

Margary's is an English process, and appears to be contemporary with that of the French (M. Boucherie's). It differs from the latter, both as regards the intensity of the solution and the method of application. Margary recommends that only 7 or 8 gallons of water should be added to each pound of the salt. The materials are placed in a tank, and the timber is allowed to remain until thoroughly steeped, the time required being about two days per inch of the thickness of the timber.

Kyan's process consists of steeping the timber in bi-chloride of mercury (corrosive sublimate), in the proportion of 1 lb. of the sublimate to 15 gallons of water. A stronger solution than the above is recommended for the best effects, and also injection under pressure similar to the former processes.

Payne's is a double process, two chemicals being separately applied. A partial vacuum is created by the condensation of steam, and upon the admission of a solution of sulphate of iron. The latter is said to find its way, even to the heart of heavy timber, through the pores rendered empty by the extraction of the moisture. Sulphate of lime is then injected, and a chemical action takes place between the two, rendering the material so treated not only proof

against dry rot and the attack of insects, but also uninflammable.

Gardner's process is that of washing out the sap from timber by chemical means. The process is said to occupy from one to two weeks, and is carried on in open tanks. It is said not only to preserve the lasting properties of the timber, but to render it more dense, thereby increasing its crushing resistance. Material so treated is capable of resisting the attack of insects, and is also rendered uninflammable.

Defects.—The following are some of the defects to be found in timber:

Knots.—These are the portions of the branches of trees enveloped by the trunks, and are classed as live or dead knots according to whether they have retained or lost their nature; the latter are considered most objectionable.

Sapwood.—This is the outer portion of the tree. It is deficient in strength and liable to decay. It may be distinguished in most timber by being discoloured, and again by absorbing an abnormal amount of moisture.

Star-shakes are small shakes passing through the timber in radial planes, and often beginning at the outer surface; these are illustrated in Figs. 1, 2, 4, and 5, page 212.

Cup-shakes are illustrated in Fig. 4, page 212, and may be described as shakes separating the annual rings. In sawn timbers they sometimes sever the wood in two by passing along the entire length of the material.

Heart-shakes are large clefts passing through the heart of the timber. These should be carefully

observed in balk timbers; if they are winding in plane or twist through the length of the material, they are liable to spoil a great portion of the heart of the timber.

Twisted fibre is a defect sometimes found in timber growing on the borders of forests, and which have been subject to the action of violent winds. Timber with this defect is liable to be "short" in its grain when converted into plank.

Druxiness is a defect peculiar to special kinds of timber, such as oak and lignum vitae. It is seen in white or yellowish streaks passing with the grain of the material. A druxy knot is one that has a portion of it changed in colour and has become druxy; this usually takes place in sectors.

Doatiness is seen more particularly in the plane tree and beech, the former being subject to it even more so than the latter. It is the name given to the small elliptical-shaped spots ranging from about $\frac{1}{4}$ in. to $1\frac{1}{2}$ in. in length. In its last stages it is of a dry powdery nature.

Foxiness is the term given to the appearance of discoloration upon the surface of the material. It is the first indication of decay, and is particularly noticeable in birch.

Upsets.—This is the name given to a rupture in the continuity of the fibre. It is caused by crushing, or improper treatment in stacking or loading.

Rind-Galls.—These are caused by a local destruction of the liber or rind during the growth of the timber, from which, either by the accumulation of foreign matter or other cause, the wound has never healed.

Waney Edges.—These are edges upon which have been left small portions of the rounded surface of the log and sometimes covered with small portions of the liber or inner bark.

Conversion of Timber.—The mode of converting timber depends largely upon the variety, the purposes for which it is intended, and upon the market. In all the conifers, and with a large quantity of hard- or leaf-wood timbers, the heart should be laid bare at the earliest opportunity. This will largely reduce the tendency to split.

The Riga and Memel wainscot oak logs are cleft when placed upon the market, whilst the more modern Austrian wainscot logs are sawn longitudinally through the heart. In order to retain the silver grain of oak, logs should be cut as shown at Fig. 1, page 224, so that all boards are taken from radial planes. This method is considered expensive owing to the constant change of position in sawing and the waste of material, but most of the small triangular stuff may be utilised for the construction of mouldings. At Fig. 2, page, 224 is shown other methods of converting oak timbers, so as to retain as far as possible the silver grain. Another method of converting a log of hard-wood timber is shown at Fig. 5, the heartwood being reserved for quartering.

Fig. 4, page 224, illustrates one of the Baltic methods of converting a log. By sawing through the centre, two 10 in. by 3 in. good quality deals are obtained; whilst two thin deals are obtained from the sides, each having a quantity of sapwood at the external edges. In order to get the widest deal from a log, one piece is sometimes cut from the centre, but this piece, it must

Fig. 1.

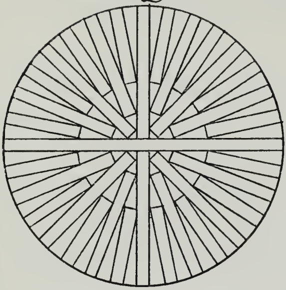


Fig. 2.

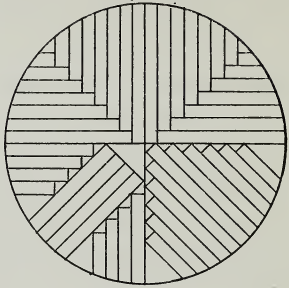


Fig. 3.

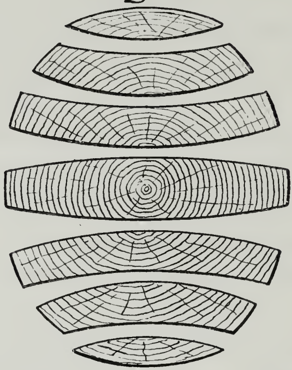


Fig. 4.

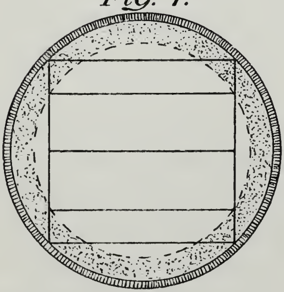
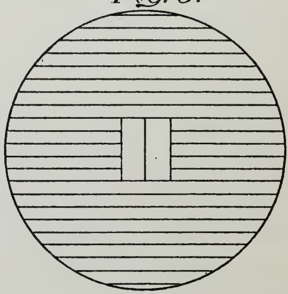


Fig. 5.



be remembered, contains the heart. From a close observation of Fig. 3, page 224, the student will be able to see how the form of pieces alter during the process of seasoning, when taken from various parts of the log. If two deals be taken from a log, one from a radial plane, and another from the outer portion of the log, at right angles to a radial plane, then the latter, upon seasoning, will be found to have shrunk in width considerably more than the former, but, apart from this fact, the latter is stronger when occupying the position of joists or bearing timbers.

From a close acquaintance with the movements of timber during the process of seasoning, the student will be able, upon examination of the end of a board, to determine what the subsequent behaviour of that piece of timber may be when placed in the work.

Classification.—Forest trees are classed by botanists under two distinct heads, Monocotyledons and Dicotyledons, according to the particular organization of the seed. But it is to the growth of the stem, or the development of the trunk, that the carpenter or joiner has to turn his attention. According as the tree develops by the formation of the woody tissue upon the interior or upon the exterior of the trunk, so is it known either by the name of Endogenous, or inward grower, or by the term Exogenous, or outward grower.

It is from the dicotyledons and conifers that we obtain our large and ever-increasing supply of timber.

This latter class of timber is again divided by the forester into two distinct classes: Needle-leaf and broad-leaf trees. Needle-leaf trees are the cone bearers, and their timbers are known as firs or pines. They are also classed under the head of soft woods; whilst

amongst them may be placed the cedar, larch, cypress, yew, and cowrie. Broad-leaf or hard-wood trees differ from the preceding class in being non-resinous. Amongst them are the poplar, chestnut, oak, elm, ash, beech, alder, etc.

In commerce the terms pine and fir are so loosely used that one might almost consider them synonymous but for the following facts:

The term "pine" is not applicable to the timber known as spruce.

"Baltic fir" is a term commonly used with all the Baltic conifers in contradistinction to the hard or leaf-woods of the same district, but it is more properly used in connection with the spruce varieties.

The term "fir" is never applied to the American pitch pine (*pinus rigida*).

The term "deal" is the commercial term sometimes applied to small stuff of the "white," "yellow," and "red" varieties other than pitch pine, from the fact that these varieties come to our markets in the form of deals.

From the above, the student will be able to understand why it is that northern pine (*pinus sylvestris*) is known by such other terms as Scotch fir, red, and yellow deal.

Standards.—A Petersburg standard is equivalent to 120 pieces, each 12 ft. long, 11 in. wide, and $1\frac{1}{2}$ in. thick. By multiplying these quantities together, we get the number of units of length, breadth, and thickness contained in the above standard, and which will be found to be 23,760; and from this number we may obtain an equivalent standard of other scantling. Suppose we require 12 ft. lengths, 11 in. wide and 2 in.

thick; then, by continued division of the constant by these latter quantities, we are able to obtain the number of deals we might have to the standard, as follows:

$$\begin{array}{r|l} 12\text{ ft.} & 23760 \\ \hline 11\text{ in.} & 1980 \\ \hline 2\text{ in.} & 180 \\ \hline & 90 \text{ deals.} \end{array}$$

An Irish standard is similar to the London standard and contains 120 pieces, each 12 ft. long by 9 in. wide and 3 in. thick—equivalent to 270 cubic ft. A square of timber is 100 ft. super; enough to cover a surface 10 ft. by 10 ft. The quality marks on Baltic deals are stencilled upon the end of the deal (usually in red), whilst the Baltic logs are scribed. American deals are sometimes marked in red chalk, upon the broad surface near the end, with one, two, or three lines, according as the quality is "firsts," "seconds," or "thirds."

TABULATED LIST OF PRINCIPAL TIMBERS.

Commercial and Botanical Appellations.		Sp. Gr.	Where Obtained.	Characteristics.	Uses.
ALDER.	*Alnus Glutinosa.*†	·78	Europe and America.	Of a light red hue. Exceedingly durable if wholly immersed in water, but soon decays if subjected to alternations of wet and dry.	Carpentry, turnery, piles, planking, and clogs.
ASH.	*Fraxinus Excelsior.*†	·75	Europe.	Of a greyish-white colour, coarse-grained, hard, tough, durable, and elastic; weathers well in positions subject to alternate wet and dry.	Wheels, bent shafts, and coach-building generally; agricultural implements, tools, and furniture.
	Fraxinus Americana.†	·48	America.		
BEECH.	*Fagus Sylvatica.*†	·75	Europe, America, and Australia.	Hard, compact, and presents a fine surface. Annual rings distinct. Medullary rays strongly marked. Of moderately quick growth, but is subject to the attack of the worm; is of a variety of colours, white, red, and brown, and fairly durable in positions either wet or dry, but soon decays when subject to alternations of wet and dry.	Coopers' and cabinet work, piles, tools, and cotters or keys, and for domestic articles.

BIRCH.	*Betula Alba.*† *Betula Nigra.*	·74	Europe. America.	Hard and close-grained, presents a surface suitable for polishing, but lacks durability.	Furniture.
CEDAR.*	*Pinus Cedrus.*‡	·50	Europe, Havana, Paraguay, and Brazil.	Soft and close-grained; takes a fine polish, and has a peculiar odour, said to be objectionable to insect life.	Furniture.
CHESTNUT.	*Castanea Vesca.*†	·65	Southern Europe and America.	Similar to oak in colour, hardly so porous and without apparent medullary rays.	Pile foundations.
CYPRESS, or CITRON WOOD.*	*Frenela Robusta.*‡		Asia, America, and Australia.	Is considered to be durable and strong, and is reputed to resist the teredo and white ant.	Carpentry and furniture. Piles and posts.
DOUGLAS FIR, OREGON PINE, SILVER FIR, and BALSAM FIR.*	*Abies Douglasii.* *Abies Pectinata.*‡	·63	America.	Enormous growth, coarse-grained and strongly marked annual rings. Logs, 30 in. × 30 in. and 200 ft. long, resembling the coarser varieties of Memel.	Marine and civil engineering.
EBONY.	*Diospyros Ebenum.*	1·2	India.	An exceedingly dense, brittle, hard, and black wood with occasional light streaks, imported in logs.	Furniture, and ornamental purposes generally.

* Pines or Firs. † Deciduous. ‡ Evergreen.

Commercial and Botanical Appellations.		Sp. Gr.	Where Obtained.	Characteristics.	Uses.
Elm.	*Ulmus Campestris.*‡ (cork barked) *Ulmus Effusa.* (spreading branched)	·53	Central and South Europe and America.	Exceedingly coarse-grained; casts and warps in drying, and is more durable when kept moist. Peculiar formation of twisted fibre and freedom from shakes.	Agricultural implements, engineering purposes, piles, pump boxes, and ships' blocks, coffins, etc.
	Ulmus Montana. (wych elm) *Ulmus Americanus.*	·70			
Greenheart.	*Nectandra Rodiæi.*†	1·1	British Guiana, South America, and West Indies.	Of a very heavy and oily nature, and, as its name implies, of a greenish hue. The heartwood is capable of resisting the teredo navalis.	Used for piling and heavy engineering work.
Hickory.	*Carya Alba.*†		America.	Tough and elastic. Grain somewhat similar to walnut, but of a yellowish-green colour, and liable to the attack of worms.	Carriage-building, barrels, barrel-hoops, and dairy utensils.
Hornbeam.	*Carpinus Betulus.*†	·76	Great Britain.	Of a yellowish-white colour. Tough and extremely hard. Is exceedingly close-grained, and presents a beautiful smooth surface.	Machinery parts.
Holly.	*Ilex Aquifolium.*‡	·76	Southern Europe.	Exceedingly hard, close-grained, and tough. New wood presents a white surface which darkens with age.	Ornamental inlay work, turnery, engraving, and for mathematical instruments.

JARRAH.	*Eucalyptus Marginata.*	1·0	Australia, S.W.	Its grain is similar to the Spanish mahogany, but without the characteristic white specks of the latter.	For piling and engineering work generally. Best furniture, and at present largely imported to this country for the purpose of street paving.
KAURI OR COWRIE.*	*Dammara Australis.*‡	·55	New Zealand.	Its colour is that of old gold; when planed, presents a silky lustre; it is tough and elastic, of exceedingly large growth, and particularly free from large knots.	Shipbuilding and joinery work.
LARCH.*	*Larix Europaea.*‡	·60	Europe.	Of a reddish-brown colour, rings even more strongly marked than in the pines. It was the bridge-building timber of the Romans; shrinks considerably, but is light and strong.	Agricultural implements, piling, planking, flooring, and boatbuilding.
	Larix Americana.‡	·58	America.		
LIGNUM-VITAE.	*Guaiacum Officinale.*	1·25	Santo Domingo.	The duramen is of a dark green colour, whilst the sapwood is yellow; of a very oily nature.	Used in various parts of marine engineering.
LIME (Bass-Wood), or CANARY WHITE WOOD.	*Tilia Europœa.*†	·76	Europe.	The English variety is very similar to sycamore. Ranging in colour from the dull grey of the English variety to Canary colour in the American, hence its name. Particularly free from knots, and is not affected by alternations of sun and rain.	Furniture, carvings, and domestic utensils, shingles, etc. Its inner bark is used for matting and rope-making.
	Tilia Americana.†		America.		

* Pines or Firs. † Deciduous. ‡ Evergreen.

Commercial and Botanical Appellations.		Sp. Gr.	Where Obtained.	Characteristics.	Uses.
MAHOGANY.	*Swietenia Mahogani.*‡	·56 to ·89	Central America, Mexico, and the Islands of West Indies.	Spanish is considered the best, and possesses the small white characteristic specks. The mahogany of St. Domingo is tough and durable, not so brittle or cross in its grain as the former type. Cuba, a softer variety of lighter colour. The wood from Honduras is of lower specific gravity, and is known as bay-wood.	Best class of joinery, hand-railing, interior fittings, and furniture.
OAK. (British.)	*Quercus Robur.*† *Quercus Pedunculata.*† *Quercus Sessiliflora.*†	·95	England and North of France.	*Q. Pedunculata* and *Q. Sessiliflora* have both been classed under the head of *Q. Robur.* In the converted timber it is a difficult matter to distinguish between the two. In the growing timber the fruit of the former is found upon long stems or peduncles, whilst the latter have short stems and clustered fruit. The Polish oak shipped at Memel and Stettin are evidently varieties of this same class.	Agricultural implements and exterior architectural work.
OAK. (South American.)	*Quercus Virens.*†	·85	South America.	The *Q. Virens*, or live oak, is a native of the northern portion of South America. It is a valuable	Shipbuilding.

				timber, but not shipped to this country. *Q. Alba* is another variety from South America. It is of a light colour, but lacking in durability.	
Oak. (Canadian.)	*Quercus Rubra.*†	·75	North America and Canada.	An oak of lower specific gravity than the former variety, and consequently more porous; has a reddish hue in drying, but a beautiful clash.	Wainscotting and cooperage.
Pine.* (Yellow.)	*Pinus Strobus.*‡	·48	America.	Of a pale straw colour, with characteristic black streaks; particularly free from knots; does not warp and twist in drying; easy to work; takes glue well.	Internal joinery, panelling, foundation for veneering, pattern-making.
Pine.* (Yellow Deal.)	*Pinus Sylvestris.*‡	·49	Russia: Petersburg, Archangel, Onega, Narva. Sweden: District bordering the Ljusne, Gefle, Soderhamn, Hudikswall, Sundsvall, Hernösand.	Is of a yellowish-white or pale straw colour and particularly clean from the Russian and Swedish ports. The timber from the former ports, though clean, is liable to shakes, that from St. Petersburg being the best. From the Swedish ports some splendid yellow deals are obtained, especially from Ljusne.	Joinery.

* Pines or Firs. † Deciduous. ‡ Evergreen.

Commercial and Botanical Appellations.		Sp. Gr.	Where Obtained.	Characteristics.	Uses.
PINE.* (Red Deal.)	*Pinus Sylvestris.*‡	·54	Prussian ports: Memel, Dantzic, Stettin.	Of the same botanical class as above, but more strongly marked in the annual rings. But few deals are imported; by far the larger trade is in balk timber, large quantities being reserved for the shipbuilding trade.	Carpentry and engineering work.
PITCH PINE. (Southern.)	*Pinus Rigida.*‡	·66	Savannah (South Carolina State), Darien (Georgia State), Pensacola (Florida State).	Highly resinous; annual rings strongly marked, presenting a surface particularly rich in colour. Durable, more especially when it is allowed to retain a large quantity of its resinous matter. This latter element is objectionable for joinery purposes, as it renders the material more liable to shrink and expand with changes in the atmosphere than would otherwise be the case.	The heavier kinds (resinous) are used chiefly for engineering work, whilst the lighter kinds are largely used in church, school, and office fittings and furniture, and formerly for ships' masts.
ROSEWOOD.	*Dalbergia Latifolia.* *Dalbergia Nigra.*	1·2	Southern India and Brazil.	A beautiful, hard, tough, close-grained, and fragrant wood, presenting a clean and smooth surface for polishing.	Furniture, turnery, etc.
SPRUCE FIR.*	*Abies Excelsa.*‡	·49	Norway and Sweden.	Exceedingly white wood, more especially that from Christiania; with a silky lustre, but liable to cast, warp, and shrink, and lacking in durability.	Packing cases, flooring, and inferior carpentry; smaller stuff used for spars, rickers, and scaffold poles.

	Abies Nigra.‡		America.	Characteristic black, hard, and loose knots, but otherwise as above.	
SYCAMORE.	*Acer pseudo-plantanus.*†	·69	Europe.	White or yellowish-white in colour, hard, tough, and close-grained timber; presents a good surface for polishing; in many respects similar to English lime.	Turnery and domestic articles.
TEAK.	*Tectona Grandis.*	·75	Burmah.	Of a rich golden-brown colour; porous; similar in grain to that of oak, but without apparent clash; durable, and shrinks but little.	Shipbuilding and joinery.
WALNUT.	*Juglans Regia.*†	·65	Europe.	Of a rich black-brown colour, with occasional light streaks; close-grained and strong, but liable to the attack of worms. Burrs are the excrescences of the timber, and, being figured, are highly valued.	High-class joinery, furniture, and musical instruments.
	Juglans Nigra.†	·50	America.	A darker variety with a violet hue, straight in grain, and more porous.	
YEW.*	*Taxus Baccata.*‡	·80	Europe and America.	Of a rich reddish-brown colour, with annual rings strongly marked; tough and elastic; exceedingly durable in moist situations.	Furniture and domestic articles.

* Pines or Firs. † Deciduous. ‡ Evergreen.

CHAPTER XIII.

MECHANICS OF CARPENTRY.

The effect of force upon matter is to produce, or tend to produce, an alteration of form, position, or volume.

These alterations of form or volume are called strains, and the forces which produce them stresses.

The following table gives some of the stresses met with in carpentry, the strains they produce, and the mode of fracture, if any :

Stresses.	Strains.	Mode of Fracture.
Tension.	Elongation.	Tearing away.
Compression.	Shortening.	Crushing.
Transverse.	Bending.	Breaking across.
Shearing.	Distortion.	Cutting, as with a pair of scissors.

For the present purpose it will be convenient to consider a structure as an erection, consisting of one or more members so bound or secured together as to be capable of resisting, without any great amount of motion, any external or internal forces.

The forces that a structure may be called upon to support or resist are as follows : (1) Gravitation, due to internal or external loads, such as the roof and its

load, including snow; (2) Wind pressure. The first, gravitation, acts downwards, and in a perpendicular line. This is met, and, if equilibrium is to be maintained, is resisted by the reaction of the walls. The second, wind pressure, acts in an inclined direction, but is calculated as normal or at right angles to the surface upon which it impinges or strikes.

Newton's Third Law of Motion is as follows: "To every action there is always an equal and opposite reaction, or action and reaction are always equal but opposite in direction." From this, we see why it is that walls, or pillars supporting a loaded beam, must offer together a resistance equal to the beam and its load. These are termed parallel forces, because they act parallel to each other.

In order to discuss the action of a force, we require to know at least the following:

(1) Its magnitude.
(2) Its line of action.
(3) The sense of the force or the direction in which it acts.
(4) Its point of application.

All these particulars may be represented graphically; that is, they may be represented by points and lines. We are accustomed to represent a quantity numerically, as 4 inches, 6 tons, 10 days, etc.; but, by the mutual understanding that a foot is the unit, we may say that a yard measure represents three. Again, by changing the unit to an inch, we may say that the same yard measure represents thirty-six; and so on, by a proper understanding of the unit employed, we may, by a line of fixed length, represent quantity or magnitude.

Again, the student will readily see that, by the position occupied by a line, the direction of a force may always be represented.

FORCES ACTING AT A POINT.

Parallelogram of Forces.—If two forces acting at a point be represented, both in magnitude and direction, by two straight lines drawn from a point, and if a parallelogram be constructed having these two lines for its adjacent sides, then that diagonal of the parallelogram which passes through the point of application of the forces will represent their resultant, both in magnitude and direction.

Example (Fig. 103).—Two forces of 5 lbs. and 7 lbs. respectively act at a point *C*, and at an angle equal to *A*. Find their resultant.

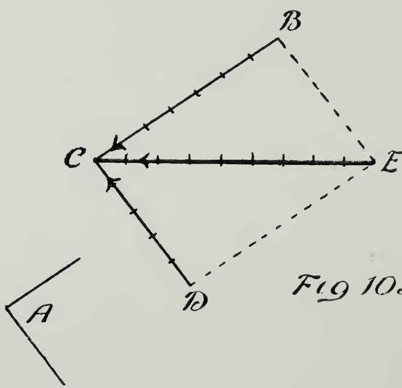


Fig 103

Draw two lines *BC* and *DC* equal in length to 5 and 7 units respectively, including an angle equal to *A*, and intersecting at point *C*. Complete the parallelogram

CBED. Then the diagonal *EC* passing through the point of application *C* represents, both in magnitude and direction, the resultant. The resultant force is one that produces a result equal to a combination of others, and the forces producing it are known as components. The resultant in the example given will be found to be 9 lbs. as measured by the number of units contained in it.

N.B.—The equilibrant is equal and opposite to the resultant.

Triangle of Forces.—If three forces acting at a point be represented in magnitude and direction by the sides of a triangle taken in order, then the forces will be in equilibrium.

Example (Fig. 104).—Three forces *AB*, *BC*, and *CA* are represented as acting at the point *O*. Find, by the principle of the triangle of forces, if they are in equilibrium.

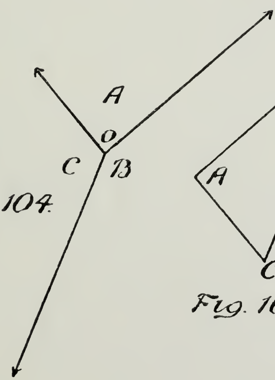


Fig 104

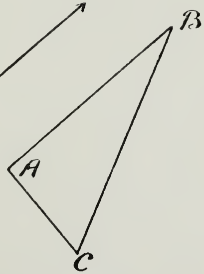


Fig. 105

N.B.—In this case Bow's Notation has been used; the method may be briefly described as follows: Assign a letter to each of the surrounding spaces as

separated by the lines of force (Fig. 104). Then in the reciprocal figure 105, lines representing the forces will have, at their extremities, letters corresponding to those appearing in the spaces of the former figure. In the case before us the triangle closes; we may therefore consider the forces are in equilibrium.

Polygon of Forces.—If any number of forces act at a point, and if, starting from any point, a line be drawn equal to and in the same direction as the representative of one of the forces, and from its last extremity another line be drawn equal to and in the same direction as the representative of the next force, and so on until lines have been drawn representing each force; and if from the point so arrived at a line be drawn to the starting point, then that line shall represent, both in magnitude and direction, the equilibrant of the forces. If, when all the forces have been represented in the reciprocal figure, the point commenced with should be found to coincide with the last one, then the forces will of themselves be in equilibrium.

Example (Fig. 106).—Let the lines *AB*, *BC*, *CD*, *DE*, and *EA* represent, in magnitude, forces acting in the direction of the arrow points through the point *O*. Find, by a reciprocal figure, whether the forces produce equilibrium or not.

Assign letters to each space as separated by a line of action. From any point, as *A* (Fig. 107), draw the line *AB*, equal in magnitude, parallel in direction to *AB* (Fig. 106), and terminating in point *B*. From point *B* draw *BC* equal in magnitude and parallel in direction to *BC* (Fig. 106). Repeat until each force has been represented, then, if the polygon be closed,

the forces represented in Fig. 106 are in equilibrium. If not, draw a line closing the polygon; this line represents the equilibrant, or force required to produce equilibrium.

These principles of the parallelogram may be applied to the solution of stresses in structures, so that the nature and intensity of the stress in any member of a framed truss may be readily obtained.

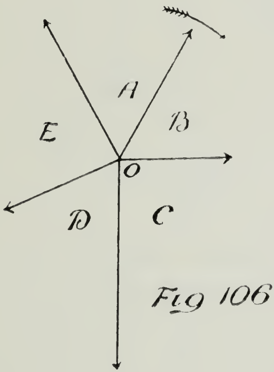


Fig 106

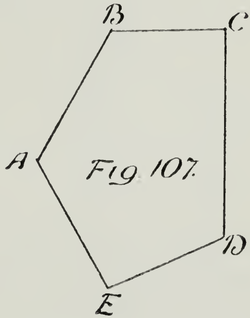


Fig 107

As an example, take the jib crane represented in Fig. 108. Here we have two members of the bracket AD and AC produced, supporting the load W at the point A. As the directions of the three forces are known and the magnitude of the one (W), we may readily complete the figure. Let AB represent the magnitude of the load W; then by completing the parallelogram in BC and CD, the tension of the tie-rod is measured by the line AD, and CA is the amount of force exerted in the compression boom to produce equilibrium.

Applied to the couple roof, the parallelogram of

forces may be used to determine the stresses set up in the rafters.

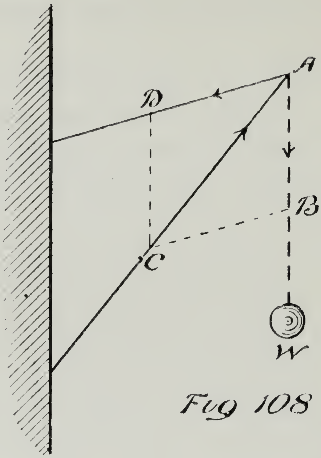


Fig 108

The loads upon roof trusses, although distributed along the blade, may be considered as being concentrated at the joints, as it is by way of the joints that the load is passed to the various members (Example, Fig. 109). The load W is here hung from the apex A, and its magnitude is measured by AD.

The load is evidently supported by the rafters, and therefore certain stresses are set up within them, due to the load W; these act along the lines AB and AC, and it is here proposed to find the amount of such stresses, in order to be able to correctly estimate the amount of material required to resist those stresses. The magnitude and direction of the resultant AD being known, and the direction of the two components (in this case the rafters) being known, complete the parallelogram $AFDE$. FA then

represents the internal stress set up in *AB*, and *EA* the internal stress set up in *AC*. The irregular or unsymmetrical truss has here been selected as affording a more interesting example than would be afforded by a symmetrical one. The student will see that as the load *W* approaches the wall at *B*, so the inclined

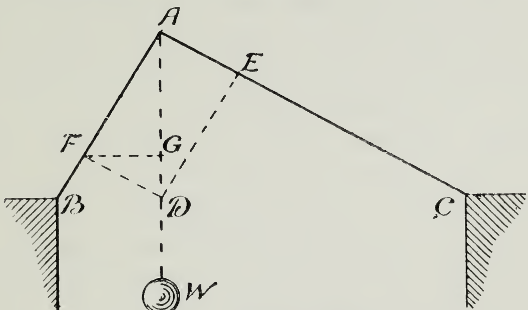


Fig. 109.

rafter *AB* will become more steeply pitched until the load *W*, or the line through which it acts, touches the wall, then *AB* will become vertical and will support the whole of the weight *W*. As it is, the load borne by *AC* and as measured by *AE* is much smaller than that in *AB*. This the student will now see is due to the fact that the load is nearer to the point of support at *B*.

Before passing on to the consideration of the more complicated structures, it will be advisable to see what takes place within the walls, as it is obvious the stresses passing down the rafters must be resisted.

It has been said that for every action there must always be a reaction. The walls in each case must therefore be capable of offering an oblique resistance equal and opposite to the forces along the rafters.

In some classes of roofing the walls would require to be abnormally thick to resist this oblique thrust; it is therefore desirable to find out what other support will be equivalent to it, and this is done by resolving the oblique force along the rafter into its vertical and horizontal components; this is shown at Fig. 109 as being equal in magnitude and direction to *GA* and *FG* respectively. It is assumed here, that having the adjacent sides, the whole of the rectangle upon *FG* and *GA* has been constructed.

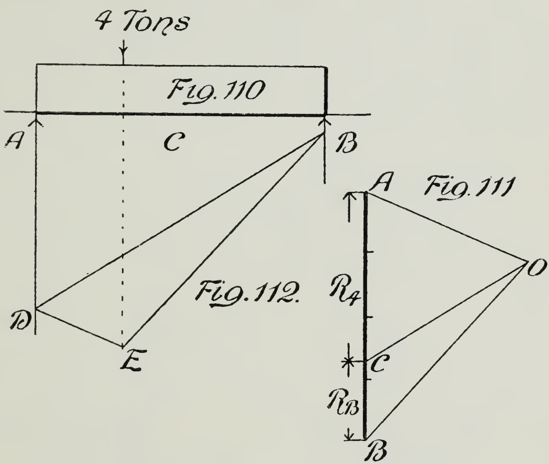
Parallel Forces.—These are illustrated by the vertical loads borne by a structure and the upward resistance offered by the supporting walls, and, if equilibrium is to be maintained, these opposing forces must be equal. With symmetrical structures uniformly loaded we readily assume that the weight is equally disposed between the two walls—half the load to each. It is now proposed to show how unsymmetrical loads are disposed between two walls.

Fig. 110 represents a beam supported at *A* and *B*, and loaded unsymmetrically with 4 tons. Find, graphically, what portion of the load (irrespective of the weight of the beam) is borne by each of the walls.

From any point *A* (Fig. 111) set down a vertical line *AB*, representing by scale 4 tons. Select any pole *O*, and join *OA* and *OB*. From the points of support, and through the load (Fig. 110), let fall perpendicular lines. From any point *D* in the vertical line through *A* (Fig. 110) draw *DE* parallel to *AO* (Fig. 111), intersecting the vertical line through the load at *E*. Through *E* draw *EB* parallel to *BO* (Fig. 111), and intersecting the vertical line through *B*. Join *DB* (Fig. 112); this is the closing line of what is known

as the funicular[1] polygon *BDE.* If through the pole *O* (Fig. 111), a line be drawn parallel to the closing line of the funicular polygon and intersecting the "line of loads" (*AB*) in point *C*, then *CA* and *CB* represent graphically the portions of the load carried by the walls at *A* and *B* respectively.

Line of Loads.—If the external forces acting on the beam of Fig. 110 produce equilibrium, or remain supported, these forces must, when represented by equivalent lines, form a closed polygon.



If the student will from point *A* (Fig. 111) draw the line *AB* equal to the downward load on the beam, and from the point so arrived at draw *BC* equal and parallel to the upward reaction at *B*, and from the point *C* draw *CA* equal to the upward reaction at *A*, he will find that he has arrived at the point of commencement, and that he has completed a polygon of

[1] From the Latin *funis*, 'a rope or chord.'

forces; but all the forces being parallel, the polygon of forces is represented by a straight line. As this line represents the external forces on the structure all acting vertically, it is given the name "line of loads," in contradistinction to the polygon of the internal forces, called the "stress diagram."

Polar Diagram.—Attached to the line of loads (Fig. 111) a series of lines are drawn from a pole *O* to the line of loads; this is termed the "polar diagram."

Reciprocal figures are those figures, the lines of which bear a corresponding relation one to the other. Figs. 104 and 105 are reciprocal, as also are Figs. 106 and 107. The funicular polygon and the polar diagram are reciprocal figures.

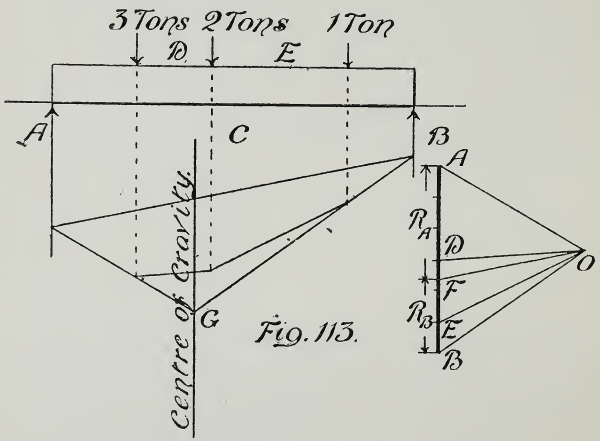


Fig. 113.

Another example of an unsymmetrically loaded beam is represented at Fig. 113. In this case a series of loads are applied. It is proposed, by means of the

polar diagram and the funicular polygon, to find not only the reactions at the walls, but the centre of gravity of the loads, or the line through which their resultant acts.

First set down the line of loads *ADEB* equal to the sum of the loads, and from any point *O* construct the polar diagram *OA*, *OD*, *OE*, *OB*.

Construct the funicular polygon as in the last example; the external lines will, if produced, intersect in point *G*. Through *G* draw the vertical line, which line passes through the centre of gravity of the loads. If through the point *O*, in the polar diagram, a line be drawn parallel to the closing line of the funicular polygon and intersecting the line of loads in point *F*, then *FA* represents that portion of the loads borne at *A*, whilst *FB* represents the portion borne at *B*.

Mathematically, the reactions at the walls *A* and *B* may be found as follows: The beam represented in

Fig. 114.

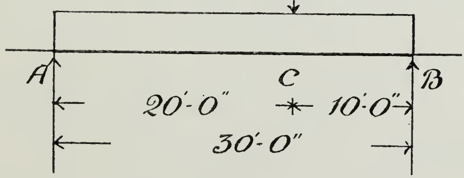


Fig. 114 spans an opening of 30 ft. and rests at its extremities at points *A* and *B*; it supports a concentrated load of 12 tons at *C*—a point 10 ft. from *B*. Neglecting the weight of the beam itself, find the reactions at *A* and *B*.

Reaction at A

$$= \frac{\text{Weight at } C \times CB}{\text{Span}} = \frac{12 \times 10}{30} = 4 \quad \text{tons.}$$

Reaction at B

$$= \frac{\text{Weight at } C \times CA}{\text{Span}} = \frac{12 \times 20}{30} = 8 \quad \text{tons.}$$

$$\text{Total Reactions} = 12 \text{ tons.}$$

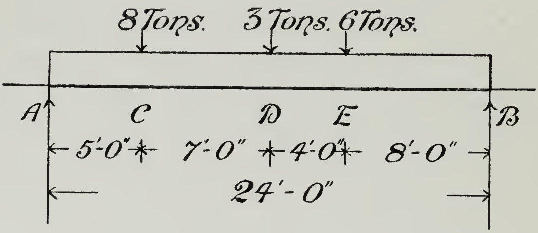


Fig. 115.

Taking the example shown at Fig. 115, the reactions may be found by taking each load individually and summing the result as follows:

Reaction at A due to the load at C

$$= \frac{\text{Weight at } C \times CB}{AB} = \frac{8 \times 19}{24} = 6\tfrac{1}{3} \text{ tons.}$$

Reaction at A due to the load at D

$$= \frac{\text{Weight at } D \times DB}{AB} = \frac{3 \times 12}{24} = 1\tfrac{1}{2} \text{ tons.}$$

Reaction at A due to the load at E

$$= \frac{\text{Weight at } E \times EB}{AB} = \frac{6 \times 8}{24} = 2 \quad \text{tons.}$$

$$\text{Total Reaction at } A = 9\tfrac{5}{6} \text{ tons.}$$

Reaction at B due to the load at C

$$=\frac{\text{Weight at } C \times CA}{AB}=\frac{8 \times 5}{24}=1\tfrac{2}{3} \text{ tons.}$$

Reaction at B due to the load at D

$$=\frac{\text{Weight at } D \times DA}{AB}=\frac{3 \times 12}{24}=1\tfrac{1}{2} \text{ tons.}$$

Reaction at B due to the load at E

$$=\frac{\text{Weight at } E \times EA}{AB}=\frac{6 \times 16}{24}=4 \text{ tons.}$$

$$\text{Total Reaction at } B=7\tfrac{1}{6} \text{ tons.}$$

$$\text{Total Reactions}=\overset{\text{Tons.}}{9\tfrac{5}{6}}+\overset{\text{Tons.}}{7\tfrac{1}{6}}=\overset{\text{Tons.}}{17}=\text{Total Load.}$$

By a collection of the quantities in the following form, the same end may be obtained:

Reaction at A

$$=\frac{\text{W. at } C \times CB+\text{W. at } D \times DB+\text{W. at } E \times EB}{AB}$$

$$=\frac{8 \times 19+3 \times 12+6 \times 8}{24}$$

$$=\frac{152+36+48}{24}=\frac{236}{24}=9\tfrac{5}{6} \text{ tons.}$$

Reaction at B

$$=\frac{\text{W. at } C \times CA+\text{W. at } D \times DA+\text{W. at } E \times EA}{AB}$$

$$=\frac{8 \times 5+3 \times 12+6 \times 16}{24}$$

$$=\frac{40+36+96}{24}=\frac{172}{24}=7\tfrac{1}{6} \text{ tons.}$$

$$\text{Total Reactions}=17 \text{ tons}=\text{Total Load.}$$

The former processes will be better understood when

the student knows what is meant by "the moment of a force about a point."

The moment of a force about a given point is a measure of the tendency of the force to rotate about that point, and, as both force and distance enter into its consideration, it is expressed in terms of the units employed; thus in Fig. 116, the force of 4 tons acts at a distance of 5 ft. from the point *O*. The measure of the tendency of the force *AB* to rotate about the point *O* is therefore 4 tons by 5 ft. or 20 ft.-tons, and is equivalent to 20 tons acting at the distance of 1 ft. from the same point, or to 1 ton acting at a distance of 20 ft. The student should, by comparing the above equivalents as illustrated at Fig. 117, see

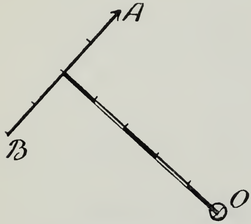


Fig. 116.

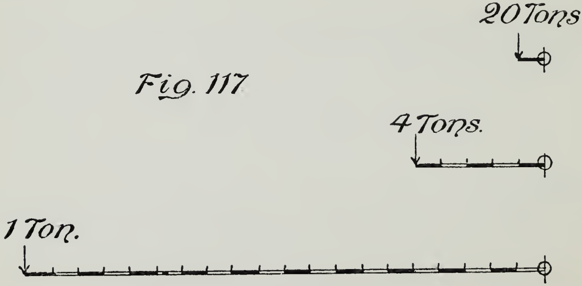
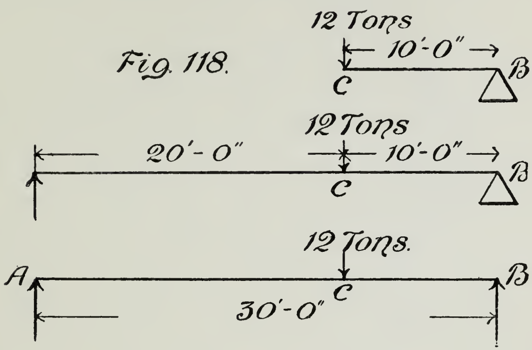


Fig. 117

the advantage gained by extending the distance, or "arm of the lever," as it is sometimes called. At Fig. 118 is represented a similar set of forces to those given in Fig. 114, the beam being here represented by a single line, the distances and lettering being the same. The support given by the

wall is here represented by the little triangle or fulcrum, the distance CB and load at C being 10 ft. and 12 tons respectively. Taking moments about

Fig. 118.



the point B, we have a force of 120 ft.-tons. Now, if we extend the arm of the lever to the distance between the supports of Fig. 114, viz., 30 ft., we shall be able to find what upward force is required at A to equilibrate the load or force at C as follows:

$$\text{Force at } A \times AB = \text{Force or load at } C \times CB;$$

$$\therefore \text{Force at } A = \frac{\text{Force or load at } C \times CB}{AB}$$

$$= \frac{12 \times 10}{30} = 4 \text{ tons.}$$

Theory of Beams.—By a sufficient acquaintance with the foregoing, we are able to investigate the relative strengths of cantilevers and beams under varying methods of load and support.

For this purpose we shall require to extend the definition of the "moment of a force," and, as it is also a measure of the tendency to bend the beam

or cantilever, we shall find it more convenient to consider it as the bending moment of a load, or simply as the "bending moment." Taking the case of the cantilever, (Fig. 119), we see that the bending

Fig. 119.

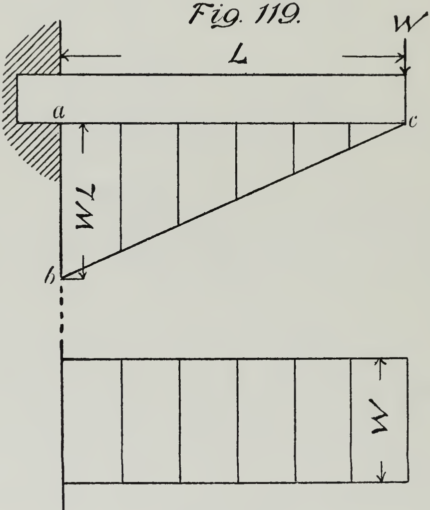


Fig. 120.

moment is equal to the weight *W*, multiplied by the length *L* (expressed as *WL*). Graphically, this may be represented at any position along its length, by scaling *ab* to represent this quantity; then by joining *cb* we have a triangle *abc* representing a bending moment diagram in which any vertical ordinate represents the B.M. (bending moment) of the cantilever at that section. The student should here observe that the B.M. is a varying quantity, and in the case of the cantilever is at a maximum at *ab*.

Now the strengths of two beams are in the inverse ratio of their maximum B.M.; and taking the canti-

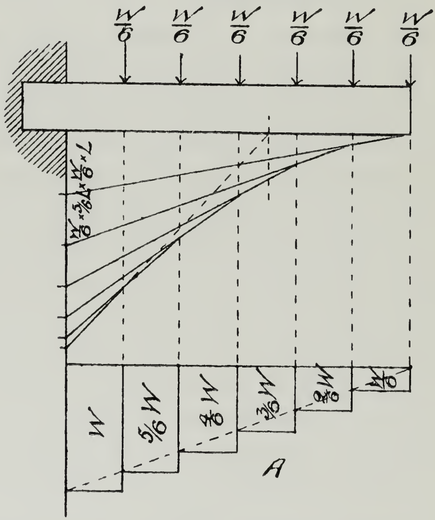
lever as the standard, the equation will be represented as follows:

$$\frac{\text{Strength of beam under consideration}}{\text{Strength of standard cantilever}} = \frac{WL}{\text{Max. B.M. of beam under consideration}}.$$

Before proceeding to describe the method of obtaining the bending moments of beams generally, it will be advisable to consider another force acting upon beams, called the shearing force. This may be vertical or horizontal. Fig. 94 represents a beam built up of a series of thin separate laminae horizontally. A slight load will be sufficient to cause the horizontal laminations to slide one over the other. In the solid beam the cohesion of the material itself resists the tendency to a great extent, varying with the cohesive strength of the material. There is also a vertical shear to contend with, as shown at Fig. 120. The semi-beam or cantilever is here split up into a series of vertical laminations, kept together for the sake of illustration by a strong elastic core. By a small pressure upon the top, in any position, the laminations may be made to slide vertically over each other. This tendency varies with the manner of loading; in the case of the cantilever (Fig. 119) it is constant throughout and equal to the load W. With cast and wrought iron beams or girders, where the sectional area is small, the consideration of shearing is very important; but with rectangular timbers, where the working section is so much greater than the effective sectional aréa, the consideration of shearing is not so important, but should still demand the student's careful attention.

Fig. 121 represents a cantilever loaded symmetrically along its length, the bending moment diagram of which is constructed by superimposing a series of triangles one on the other, and in such a way that their apices

Fig. 121.



are each upon vertical lines, passing through the loads they respectively form the diagram for. Their bases are in a vertical line common to all, and are scaled each to a length equal to the weight multiplied by its distance from the wall end, the unit employed being in terms of the above factors.

The base of the first triangle will be equal to $\frac{W}{6} \times L$ (the full length); the next will be equal to $\frac{W}{6} \times \frac{5}{6}L$, and so on, until the last is equal only to $\frac{W}{6} \times \frac{1}{6}L$.

The B.M. diagram for a distributed load will have a parabolic curve. The loads in the diagram of Fig. 121 being concentrated at certain points, the parabolic curve of the B.M. diagram is made up of a series of straight lines which gradually merge into the true curve as the loads are placed closer to each other. The shearing stress diagram at A is also composed of a series of steps in this case, and would merge into the triangle shown by the dotted line were the load spread uniformly over its length. The bending moment would in that case be equal to the weight acting through its centre of gravity, or $W \times \frac{L}{2}$, or half that of the standard cantilever (Fig. 119), and, as their strengths are in the inverse ratio of their Max. B.M., we may consider the former to be twice as strong as the latter. In Fig. 122 we have

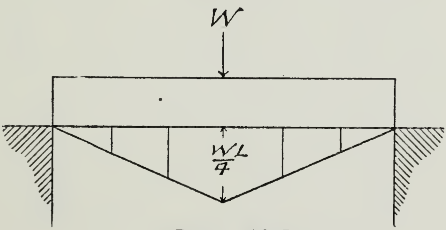
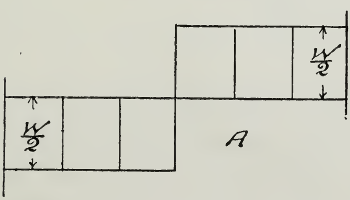


Fig. 122.

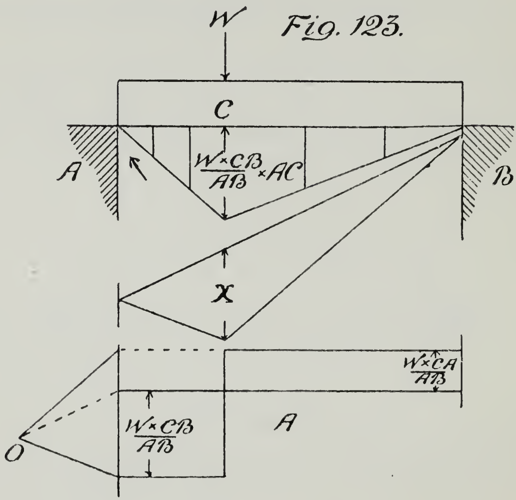


a rectangular beam, supported at its extremities and loaded with a weight (W). It is here obvious that

half the weight goes to one abutment and half to the other; the B.M. is therefore equal to half the load multiplied by half the length, $\frac{W}{2} \times \frac{L}{2} = \frac{WL}{4}$, whilst the shearing stress is equal to $\frac{W}{2}$.

Fig. 123 shows a rectangular beam loaded unsymmetrically. The Max. B.M. is equal to the reaction at the wall multiplied by its distance from the centre of gravity of the load, or $\frac{W \times CB}{AB} \times AC$. It may be

Fig. 123.



seen here that the funicular polygon may also be the B.M. diagram, but the vertical line X must be made equal to the Max. B.M. The shearing stresses are found graphically by means of a polar diagram and the funicular polygon, the dotted line being drawn parallel to the closing line of the polygon.

Fig. 124 represents a beam loaded uniformly along its length. The B.M. diagram and also that of the shearing forces are drawn as in the previous figure.

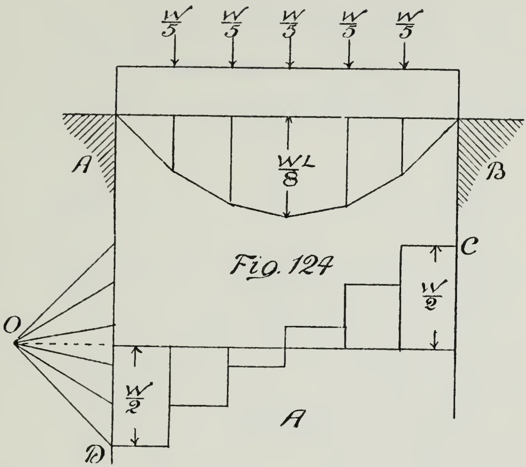


Fig. 124

It will be seen from the figure that the B.M. diagram approximates a parabolic curve; the closer the lines of loading, the more truthful will the parabolic curve be represented. The Max. B.M. is found as in the figure of 122, with this exception—the total load is divided in two, each half being concentrated at distances from the supports equal to a quarter of the span; then

$$\frac{W}{2} \times \frac{L}{4} = \text{Max. B.M.} = \frac{WL}{8}.$$

The example shown in Fig. 125 is that of a beam fixed into the walls at both ends. This may seem anomalous from the fact already related that the ends of beams should not be built into walls; but when a beam passes in continuation over a series of supports, those covering the central spans are considered to have

their ends fixed, and in a manner even more efficient than actually building them into walls.

The B.M. diagram is here a straight-lined figure, and, as the beam has a tendency to assume the position indicated by the dotted lines, there is a point of contrary flexure—a point at which the B.M. is nil; we may also assume that the bending moments at the centre

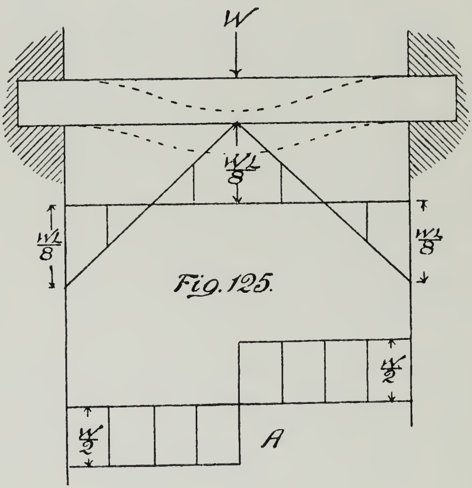


Fig. 125.

and ends are equal. From these statements we may reason that the point of contrary flexure is at distance of $\frac{L}{4}$ from each end, and hence the Max. B.M. must be

$$\frac{W}{2} \times \frac{L}{4} = \frac{WL}{8}.$$

It has been said that the vertical ordinates through the diagrams are measures of the intensity of the stresses at those points, and any unit of length, weight, or length and weight may be employed, and it must

not be forgotten that the scale used to plot the B.M. diagram is one of length and weight combined; thus $\frac{1}{8}$ in. may be made to represent inch-pounds, inch-hundredweights, or inch-tons, or even foot-pounds, foot-hundredweights, or foot-tons. It will be seen from the figures that the same scale has not been used to plot the B.M. diagram as has been used to plot the shearing stress diagram; in fact, it is often convenient to plot them by a different scale, care, of course, being taken in reading to use the same scale as that adopted for plotting.

We have seen in Fig. 109 how it is possible to obtain the stresses set up within the roof couple. It is now proposed to extend the principle to the example given in Fig. 126, namely, that of the kingpost roof truss. The total load borne by the roof is concentrated at the joints, and if the weight at each bay is divided by two, the weights may be disposed as shown in the frame diagram (Fig. 126)—one-eighth of the total load will be carried by the wall at either end, and may not be considered as acting upon the truss; the other six parts are disposed at the three other joints, two to each.

In order to find the stress diagram (Fig. 127), Bow's Notation will be used, and may be described as follows: Assign a letter to each space around the figure as separated by an external force, also to each space in the figure surrounded by members. Now, in the reciprocal figure (Fig. 127), lines having letters at either end represent corresponding lines in the frame figure having the same letters at either side.

The external forces are here parallel, therefore the polygon representing them will be a closed one, and

will be known as the "line of loads" ($ADEFGBCA$) (Fig. 127). Here C divides the loads A to B into two equal parts, and BC and CA represent the equal reactions at the walls.

To Construct the Stress Diagram.—Having constructed the "line of loads," and divided it into its several parts AD, DE, etc., commence at point A in the frame diagram (Fig. 126).

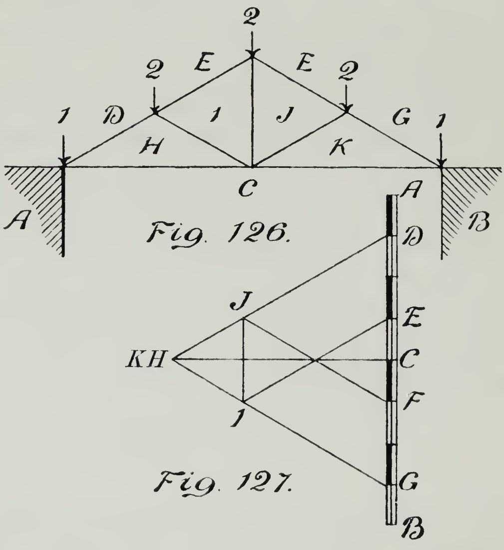


Fig. 126.

Fig. 127.

We have here four forces in equilibrium, namely, CA, AD, DH, and HC; the magnitudes and directions of the first two are known, also the directions of the last two. The magnitude of the latter may be found if from D (Fig. 127) we draw a line parallel to DH (Fig. 126), and if from C (Fig. 127) we draw a line CH parallel to its reciprocal CH (Fig. 126), and intersecting the line from D in H. These lines DH and HC (Fig.

127) will represent not only the magnitude, but the direction of the forces in the corresponding members of the frame diagram. By taking the known forces *CA* and *AD*, and examining the corresponding lines in Fig. 127, the student will see that *CA* is an upward reaction equal to four units, and passing from *A* to *D* we have a downward force equal to one unit. In order to complete the circuit around the point we have *DH* and *HC*, terminating at *C*, the point of starting; but *DH* passes downwards towards the point of support—the wall—and is therefore in compression; whilst *HC* passes in a direction away from that point, and is therefore in tension. For every joint in the frame diagram (Fig. 126) a corresponding polygon will be found in the stress diagram, which will furnish lines corresponding in magnitude and direction to those contained in the frame.

Transverse Strength of Rectangular Beams.—If we take a small piece of deal 1 in. square, and about 4 ft. long, and place it between two supports, we shall find that by bearing upon it, it deflects or is bent to an appreciable extent; but upon removing the pressure, the piece regains its former position. By gradually increasing the pressure we shall be able to reach such a point that, after removing the load, the piece fails to recover its former position. This is termed the elastic limit of the material. By an increase of the load or pressure we shall be able to arrive at such a point as to produce fracture of the material; such a point is known as its ultimate strength, and the load which caused the specimen to break is known as its breaking weight.

Now take a piece of the same class of material

7 in. wide and 1 in. thick (a floor board will do), and of the same length as in the last example. We shall, by placing it upon its flat surface and noting the weights which produce fracture, find it to be about seven times as strong as the last example, but if we turn a similar piece of 7 in. by 1 in. material upon its edge, we shall find it to be seven times stronger than when placed upon its flat, so that it is seven times seven as strong as the first specimen. From the foregoing we see that the transverse strength of rectangular timbers varies directly as the breadth and as the square of the depth; it varies also directly as the strength of the particular material employed, and inversely as the length of span or distance between the supports.

This is represented by the following formula:

$$W = \frac{b \times d^2 \times c}{L}.$$

When W = Breaking weight of a beam, girder, or bressummer under a central load,

L = Length of span in feet,

b = Breadth in inches,

d = Depth in inches,

c = Constant, found by experiment upon similar material, and which may be expressed in lbs., cwts., or tons, at pleasure, remembering always that the expression W will be in like terms to the constant.

Example.—Find the breaking weight of a beam of red pine, 8 in. deep and 5 in. wide, spanning an opening 16 ft. wide. The constant for red pine may be taken as 4 cwts.

By applying the above formula,

$$W = \frac{b \times d^2 \times c}{L} = \frac{5 \times 8 \times 8 \times 4}{16} = 80 \text{ cwt.}$$

The student is recommended to make a sketch of each example previous to working.

Cases may occur to the student in which any one of the quantities upon the right-hand side of the equation is unknown; this quantity may be removed to the left by a change of sign. The formulae for these purposes will then appear as follows:

$$L = \frac{b \times d^2 \times c}{W},$$

$$b = \frac{W \times L}{d^2 \times c},$$

$$c = \frac{W \times L}{b \times d^2},$$

$$d = \sqrt{\frac{W \times L}{b \times c}}.$$

The strongest beam is obtained when the breadth is to the depth as 5 is to 7. The following example will serve to illustrate the method of obtaining the correct breadth and depth of a beam of limited sectional area, say 150 sq. ins.:

Let x = the unit of breadth and depth, then $5x \times 7x = 150$ sq. ins.

$$\therefore\ x^2 = \frac{150}{35},$$

and $$x = \sqrt{\frac{150}{35}} = 2{\cdot}07 \text{ in. nearly.}$$

Then breadth $= 5 \times 2{\cdot}07$ in. $= 10{\cdot}35$ in.,

and depth $= 7 \times 2{\cdot}07$ in. $= 14{\cdot}49$ in.

It sometimes occurs in practice that the most economical dimensions are required for a beam of a particular class of material to cover a known span and to successfully resist a certain load as follows:

Length of span = 13 ft.
Material (red pine), therefore constant = 4 cwt.
Concentrated load = 16 cwt.
Factor of safety = 5.

This latter item is necessary from the fact that the ordinary formula supplies the breaking weight, and, in order that the beam under consideration should successfully resist the concentrated load of 16 cwt., it should be considerably stronger, in this case 5 times stronger. We must therefore calculate for a beam loaded to the extent of 5×16 cwt. = 80 cwt.

By usual formula,

$$W = \frac{c \times b \times d^2}{L},$$

or $$W \times L = c \times b \times d^2;$$

but $$\text{breadth} = \tfrac{5}{7}d,$$

$$\therefore \quad W \times L = c \times \tfrac{5}{7}d \times d^2,$$

$$\therefore \quad \tfrac{5}{7}d^3 = \frac{W \times L}{c},$$

$$d^3 = \frac{W \times L \times 7}{c \times 5},$$

$$d = \sqrt[3]{\frac{W \times L \times 7}{c \times 5}},$$

$$= \sqrt[3]{\frac{80 \times 13 \times 7}{4 \times 5}} = \sqrt[3]{364}$$

$= 7{\cdot}15$ inches (d being expressed in inches),

and $$b = \tfrac{5}{7} \times d = \tfrac{5}{7} \times 7{\cdot}15 = 5{\cdot}11 \text{ inches.}$$

The transverse strength of rectangular timbers is greatly increased by the addition of wrought-iron flitch plates, as shown in Chapter IV, firmly secured by means of bolts. Flitch plates are sometimes secured to the sides of timbers and the ultimate strength of either combination may be found by the following formula:

$$W = \frac{d^2(cb + 30t)}{L},$$

t = combined thickness of wrought-iron flitch plates (taken as about $\frac{1}{12}$th that of the total thickness of beam or girder); all other quantities represented algebraically are of the same value as in the previous formula.

CHAPTER XIV.

STAIRCASING AND HAND-RAILING.

THIS is a branch of joinery requiring a knowledge of practical geometry, and unless the apprentice shows ability in this direction it is seldom that he is brought in contact with the work. It is desirable, at an early stage of the subject, to explain some of the terms employed.

Stairs.—An assemblage of steps for the easy and convenient passage from one floor to another.

Staircase.—That compartment which contains or is intended to contain the stairs.

Tread.—That portion of the step upon which the foot rests in ascending or descending the stairs, and which should not be less in width than will permit the foot resting firmly upon the same. The least width for this purpose has been laid down as 9 in., whilst the greatest width approaches nearly double that dimension.

Going.—The going of a tread is the width of the same, as measured horizontally between the nosing of one tread and that of the next adjacent to it. This, it will be seen, is smaller than the full width of the tread. A portion of the wood used in the tread passes

beneath the riser, and is serviceable only for the purpose of making good the joint between tread and riser, and may not be considered as available for the purpose of resting the foot.

N.B.—It is to the going of the tread that reference is made in determining the proportionate width of tread and riser (see page 273). The "going" of a flight is the horizontal distance covered by that flight.

Rise.—The vertical distance between the top of one tread and the top of the next one to it.

Riser.—The vertical piece of timber passing between the treads to which the latter are secured, and which gives solidity to the step.

Flier.—A step, the tread of which is parallel throughout its length (page 278).

Flight.—A continuous series of fliers.

Winders.—Those steps, the treads of which taper in plan and permit the person passing over them to turn either to the right or left, according as the winders turn in either of these directions (see Fig. 1, page 278).

Kite.—That winder which has its centre line passing to, or near, the angle of the staircase, and is kite-shaped in plan. The kite differs from an ordinary winder in the fact that, whilst both taper in plan, the former is quadrilateral and the latter triangular (see Fig. 3, page 278).

Nosing.—The rounded front edge of a tread.

Bottle-nose.—The ordinary rounded nosing with the addition of a small scotia beneath it (see enlarged section, page 269).

Bull-nose Step.—A step with a rounded end in plan, as illustrated at Fig. 3, page 278.

Curtail Step.—The step immediately below the scroll of the hand-rail, from which it takes its form; the first step of the flight, and one which has its end shaped in the form of a volute.

Line of Nosing.—An imaginary line passing down the nosings of a flight of steps.

Newel.—The main post of a series of balustrading; the vertical post from which the hand-rail starts in dog-legged or open-newelled stairs.

Balusters.—The small vertical pillars terminating with the hand-rail at the top, and which form a guard at the open end of the stairs; they should be spaced at no greater distance from each other than 5 in. clear.

Hand-rail.—The capping piece of the balustrading; the rail upon which the hand rests in ascending or descending the stairs; usually rounded upon its upper surface and fixed at such a height as to be conveniently grasped by the hand, usually 2 ft. 7½ in. above the line of nosing (measured vertically), and to which is added at the landings half the rise.

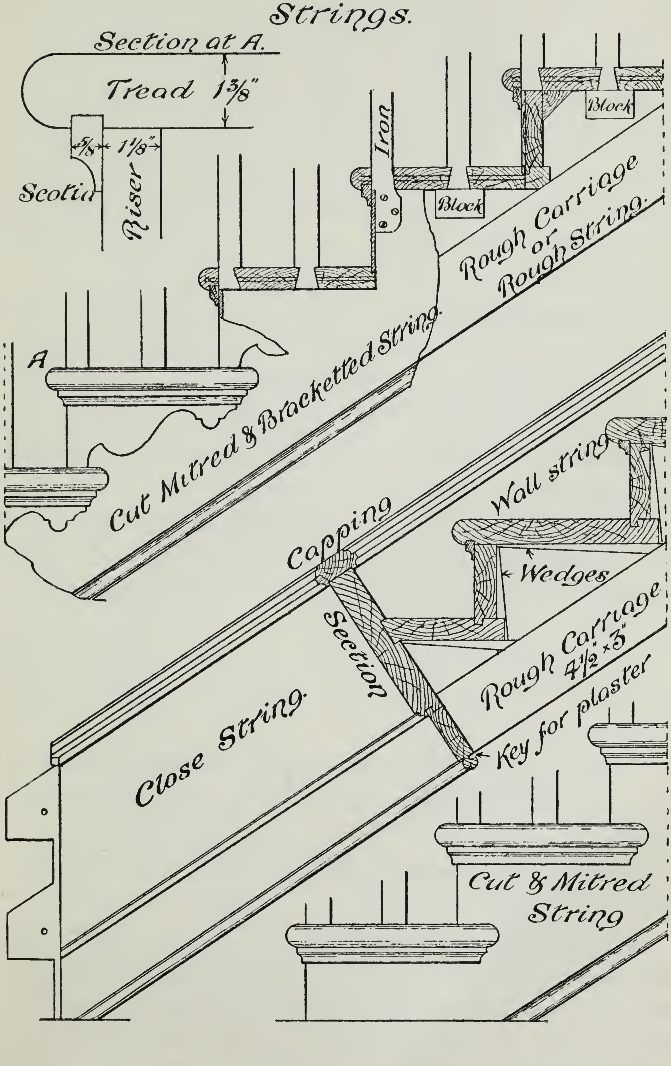
String.—An inclined board with its plane vertical, and to which the ends of the steps are made fast.

Wall-string.—That string which is adjacent to the wall.

Well-string.—The outer or exposed string; that string which carries the ends of the steps opposite to those near the wall.

Close-string.—That string which from a side view has its long edges parallel to each other (page 269). The lowest portion is termed an apron.

Cut-string.—That string which has its upper edge cut to the line of the treads and risers.



Strings.
Section at A.
Tread 1⅜"
⅝"
1⅛"
Scotia
Riser
Iron
Block
Block
Rough Carriage or Rough String.
A
Cut Mitred & Bracketted String.
Capping
Wall string
Wedges
Section
Rough Carriage 4½" × 3"
Key for plaster
Close String.
Cut & Mitred String

Notch-board.—A form of rough carriage used with open stairs in buildings of the warehouse class, and having its upper edge notched to receive the treads, hence its name (Fig. 4, page 271).

Mitred-string.—A form of cut-string not furnished with brackets, and which needs to have the vertical edges of the stepping mitred with the risers. This term is mostly used in conjunction with that of "cut-string," and then known as cut and mitred string (page 269).

Bracketed-string.—A form of cut-string provided with brackets of an ornamental character (page 269).

Wreathed-strings.—The strings of a geometrical stair which pass uninterruptedly throughout the whole height of the stairs, and which are therefore of necessity of a twisted or wreathed character.

Continued wreath or wreathed hand-rail is one which, like the wreathed-string, passes uninterruptedly throughout the stairs, and is curved, bent, or twisted in its form.

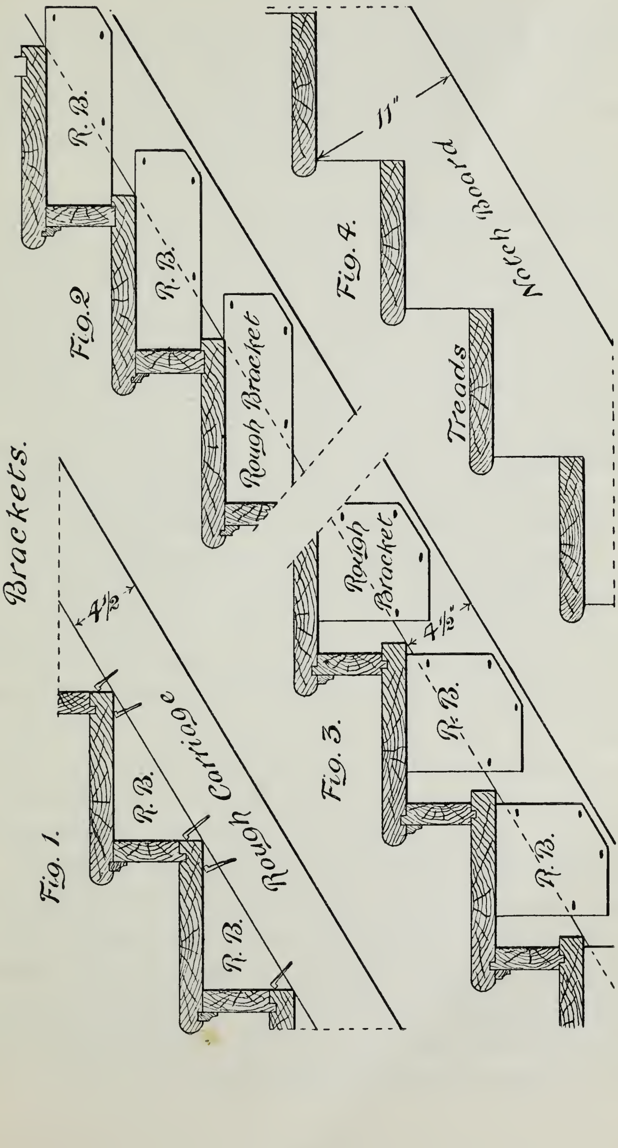
A ramp is a concave curve of the crown of the hand-rail whilst the latter continues in the same vertical plane.

A knee is a convex curve of the crown of the hand-rail, somewhat similar to the above, but opposite in direction.

Swan-neck.—A combination of ramp and knee (see page 280).

Rough carriages are pieces of rough quarterings placed beneath stairs to give them additional support; they are sometimes called rough strings, as they are often placed in corresponding positions to the strings.

Spring-trees.—This is another name for rough


Brackets.
Fig. 1.
Fig. 2
Fig. 3.
Fig. 4.
R. B.
Rough Bracket
Rough Carriage
4½
4½"
11"
Treads
Notch Board

carriages, but is more properly applied to the rough carriages below winders.

Rough brackets are blocks of wood fastened to the carriages of stairs to increase the support to the treads and prevent creaking. Figs. 1, 2, and 3, page 271, are illustrations of the various methods of rough bracketing.

Returned Nosings.—In the representations of cut-strings (page 269), the nosings are made to appear as being returned upon the ends of the treads. This is accomplished by planting on a piece of the same profile and with a grooved and tongued joint, forming when complete an effective finish, and covering the unsightly appearance of the end grain of the tread.

Landings are resting places, and are either half space or quarter space, according as they extend the whole width of the staircase or only the width of the stair; these are illustrated by Figs. 2 and 3, page 278.

Stair Planning.—Stairs have been described as being an assemblage of steps for the easy and convenient passage from one floor to another, and to secure this end it will be necessary to consider the following points. In order that stairs may not be the cause of unnecessarily fatiguing the person passing over them, they should be provided with sufficient landing-places, and the steps should be properly proportioned. Separate flights should not contain more than ten or twelve steps; at these places landings should be provided, and it is advisable to cause the adjacent flights to pass in different directions. The stairway should be broad enough to allow at least two persons passing each other with ease, and for this purpose steps should have a length of at least three feet.

Proportion of Treads and Risers.—The author does not deem it advisable to put the student in possession of a tabulated list of proportionate sizes, but to place at his disposal the means whereby he may obtain the sizes for himself, and to show the method by which they are obtained.

An easy pace along a horizontal plane has been set down as 23 in., but in passing upward in a vertical direction, it is not considered advisable to go beyond half this distance, namely, $11\frac{1}{2}$ in. In ascending stairs a person passes not only upward but forward, that is to say, he covers a small distance in each direction, vertically and horizontally; it therefore follows that, in calculating the dimensions of steps, twice the rise plus the tread must equal 23 in. From the above remarks the following formulae may be deduced, the number 23 being taken as a "constant."

$$\text{Going of tread} = \text{Constant} - \text{Twice the rise}$$
$$= 23 - 2r, \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where r = rise;

$$\text{Rise} = \frac{\text{Constant} - \text{Tread}}{2}$$
$$= \frac{23 - t}{2}, \quad\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where t = the going of the tread.

To apply the formulae given above, the student may take the following examples:

(i.) Having taken the height from floor to floor by means of a rod (storey rod), and having found that it contains equal sub-divisions of 5 in. without a remainder, and adopting this as a convenient rise; what should be the correct tread in this case?

S

By formula (1) we have

$$\text{Going of tread} = \text{Constant} - 2r = 23 - 10$$
$$= 13 \text{ inches.}$$

(ii.) What rise would be recommended for a step, the tread of which was 12 in.?

Using formula (2),

$$\text{Rise} = \frac{\text{Constant} - t}{2} = \frac{23 - 12}{2}$$
$$= 5\tfrac{1}{2} \text{ in.}$$

Numerous other examples may be taken at the student's pleasure, but he should always bear in mind that the tread must be at least wide enough to afford sufficient support for the foot, viz. not less than 9 in.

Before commencing the planning of stairs, it will be found necessary to obtain the following facts:

(1) The dimensions of the staircase or compartment which is to contain the stairs.

(2) The heights from floor to floor successively.

(3) The position and dimensions of approaches; size and position of window openings.

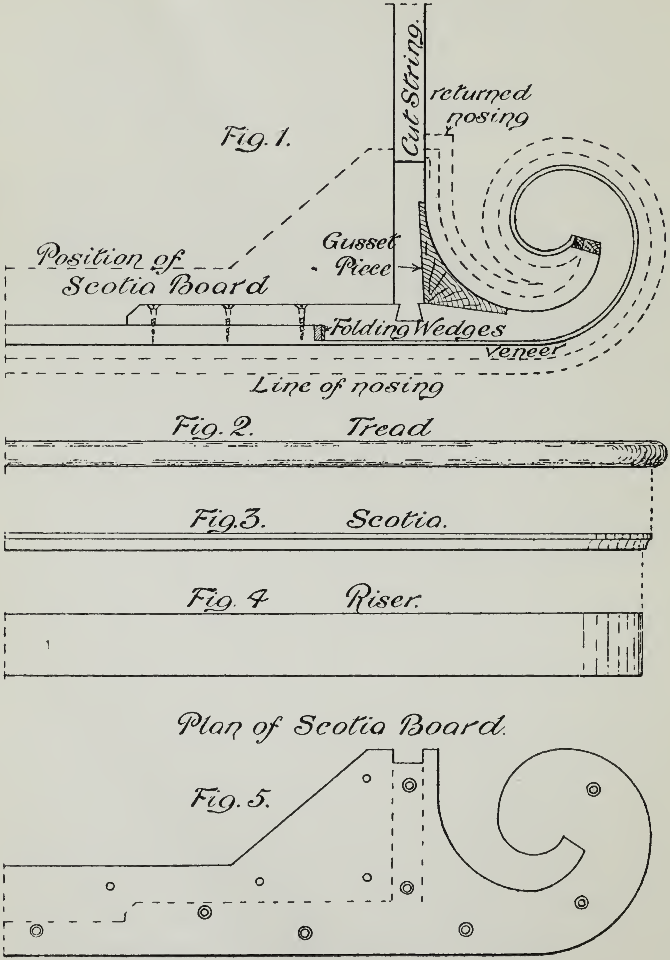
The first item will largely govern us in the particular class of stairs to adopt. The various kinds are illustrated on page 278. Winders should, as far as possible, be avoided, and should not under any circumstance begin at the top of a flight. The width of the tread of a winder is measured at a distance of 15 in. from the hand-rail; this being the position of the path over winders, the tread should at this line conform as far as possible to the other treads. The general surroundings of staircases are usually of such a diverse character that no definite rules can be laid down for the guidance of the craftsman in determining the

position for the various fliers, winders, and landings, in order to avoid interference with the means of lighting or approach. In the commoner classes of stairs no difficulty will be experienced; but with others it will require all his skill and ingenuity to devise the best possible plan, and so fulfil all the requirements necessary for a convenient and easy stair.

The construction of the various forms of steps will readily be seen from the illustrations furnished on pp. 269, 271, and 276; the tread and riser having been made, and the particular method of breaking the joint having been decided, the two are carefully glued and screwed together, and small triangular blocks about $2\frac{1}{2}$ or 3 in. long are glued to the joint at intervals of about 12 or 15 in. The steps thus constructed are inserted individually into the housings provided in the string and there glued, wedged, screwed, and blocked as illustrated.

The construction of the curtail step is one that requires to be more fully described. This step is usually constructed in three parts—namely, tread, scotia board, and riser. The tread is similar to the ordinary one, with the exception that it takes up the form of scroll of the hand-rail at its extremity. The scotia board replaces the small scotia shown in the other examples, and in this form enables the step to be constructed expeditiously, and with much greater strength; it is illustrated at Figs. 3 and 5, page 276. It is in the construction of the riser that the greatest care is required, and in which the greatest amount of labour is involved. It is usually built up of two or more thicknesses of material, firmly glued and

Construction of Curtail Step.



screwed together, and finally covered with a veneer as shown at Fig. 1, page 276.

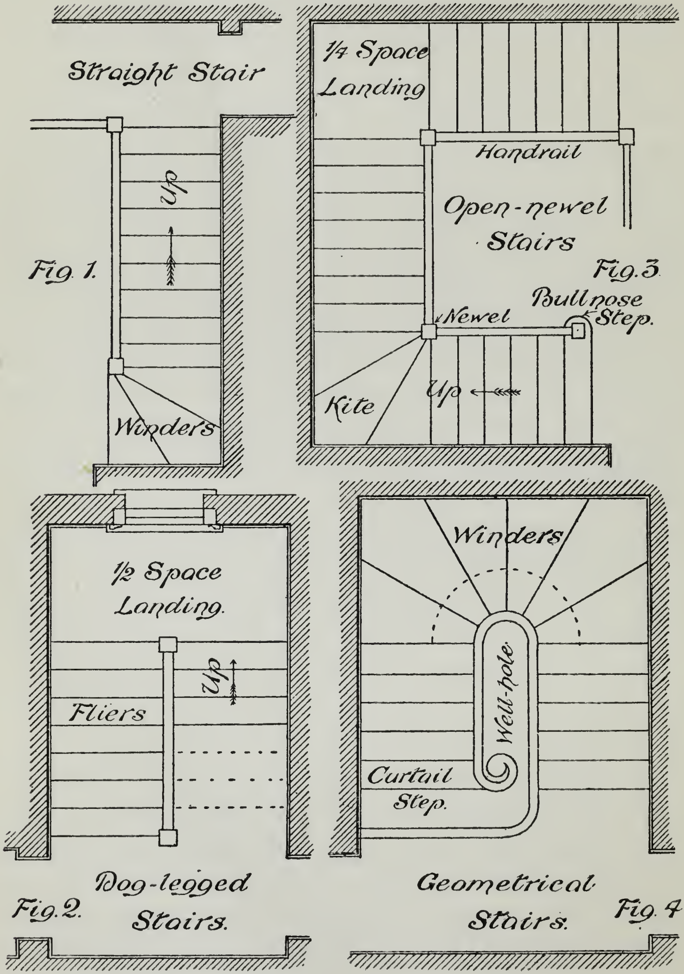
A sufficient portion at the end of the front riser is reduced to the thickness of a veneer, or about $\frac{1}{16}$ in. thick; it is then steamed or saturated with hot water, so that it becomes easily pliable, the extreme end is then held by means of folding wedges to the innermost angle of the volute, carefully glued, brought round to its correct position, and finally tightened by a second pair of folding wedges. The thick ends are then screwed together and cleaned off. A short bracket for the reception of the string is dovetailed to the solid portion of the riser at right angles to it, and the former are then halved, glued and screwed together at convenient positions, the rounded angle being made good by means of a gusset piece.

Different Forms of Stairs in Plan.—These are illustrated upon page 278. Fig. 1 represents a variety common to small cottage property, consisting of a straight flight with winders at the bottom. The hand-rail and string are here made fast to the newels by means of stump or stub tenons (drawbore pinned).

Fig. 2 represents a variety known as "dog-legged," the return flight taking an abrupt turn to a position parallel and close to the side of the first.

A larger example of the dog-legged variety is illustrated on page 280, and is here shown in plan and section with small cupboard behind the spandril framing, entered by way of the small door at the side. The necessary amount of headroom between parallel flights is here figured, and may be taken as the smallest dimensions permissible. The storey rod is also shown on this illustration, the chequered

Stairs.
Forms differing in Plan.



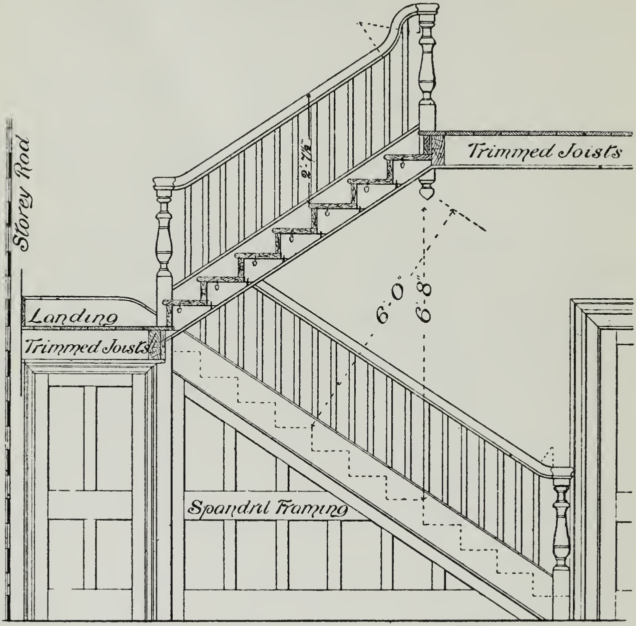
appearance indicating the number and heights of the risers.

Fig. 3, page 278, illustrates an open-newel stair, a variety suitable for wide and open staircases, and capable of being thoroughly well lighted—an important feature of a convenient stair. An illustration of the application of both the quarter-space landing and winders is here afforded, although, where possible, the latter should be avoided.

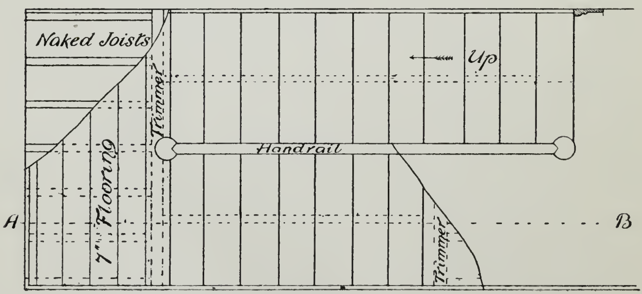
A geometrical stair is shown at Fig. 4, and may be described as a stair in which the continued wreath is used: other examples of the same variety are turret or spiral stairs (open or close newel), and stairs having an elliptical plan. The steps of the latter, as also some of the former varieties, are required to be made "balanced" or "dancing"—a name given to a particular class of winders, in which the lines of nosing do not pass through, or radiate to, the same point in plan.

Hand-railing, or that branch of it dealing with continuous wreaths, would not prove such a difficult subject as it at first sight appears, if the student would, in the earlier stages, model each example of the subject taken in hand. Much time and labour is ofttimes spent in thinking out abstruse problems which, after being solved, are not sufficiently impressed upon the student's memory to aid him in its subsequent application to practical work. The student is therefore recommended to construct models to a convenient scale, and so obtain a grasp of the subject by means which, in the end, will prove by far the most economical, both as regards time and material.

Dog-legged Stairs.



Vertical Section
on A B



Plan.

The author proposes to deal with the subject purely upon recognized geometrical methods, so that the student who has done equivalent geometrical work to, or has successfully completed the Elementary Course of Practical Plane and Solid Geometry, as set down in the Science and Art Departments Syllabus, will have but little difficulty in mastering the subject.

The hand-rail follows a line vertically over the ends of the steps, and as far as is convenient at a constant vertical distance from it throughout. A development, therefore, of the ends of the steps will reveal, as far as the height is concerned, the position of the hand-rail. For the present, in order to more easily grasp the subject, the student is asked to disregard the position of steps, also the fact that the hand-rail has substance, and to imagine the hand-rail as represented only by a line ("the centre line of rail"). When the student finds himself able to construct the "centre line of rail" he will, with very little difficulty, be able to extend his knowledge and construct the "face-mould." The next step will then be to apply the face-mould to the plank, and finally to construct the rail.

One of the most important principles the hand-railer has to remember is that oblique sections of cylinders are ellipses. The cylinder as used by the craftsman is a modification of the geometrical cylinder, and may be described as an imaginary solid composed of a right rectangular prism with hemi-cylinders attached to its two opposite and vertical faces; and which in plan is of the same outline as the well-hole. The rail or continued wreath, passing over such a form in plan, will of necessity be in

some places straight, whilst in others it will pass in a twisted manner over the segmental ends, and at these positions will take up the elliptic form.

Two systems have been adopted for finding the elliptic curve. The older and now almost extinct method was by a system of ordinates, and known as the "method by ordinates." The other and more modern method is known by the name of "tangent system," in which, in order to obtain the curve, the tangents to it are first found and subsequently the elliptic curve.

Upon examination of the various rails in plan, the curved portions will be found almost invariably to be of either of the following forms: 1st, the $\frac{1}{4}$ circle or quadrant; 2nd, an arc of a circle greater than the quadrant; 3rd, an arc of a circle less than the quadrant. The tangents to the foregoing will include the following angles, respectively: 1st, a right angle; 2nd, an angle less than a right angle (acute angle); 3rd, an angle greater than a right angle (obtuse angle). Two such cases are shown on pages 284 and 287 and serve the purpose of illustrating two out of the three cases differing in plan.

The true tangents stand vertically over their plans, varying in length with their inclinations, and giving rise to the following classification:

1st Class—Hand-rails, one tangent of which is horizontal and the other inclined.

2nd Class—Hand-rails, both tangents of which are equally inclined.

3rd Class—Hand-rails, the tangents of which are unequally inclined.

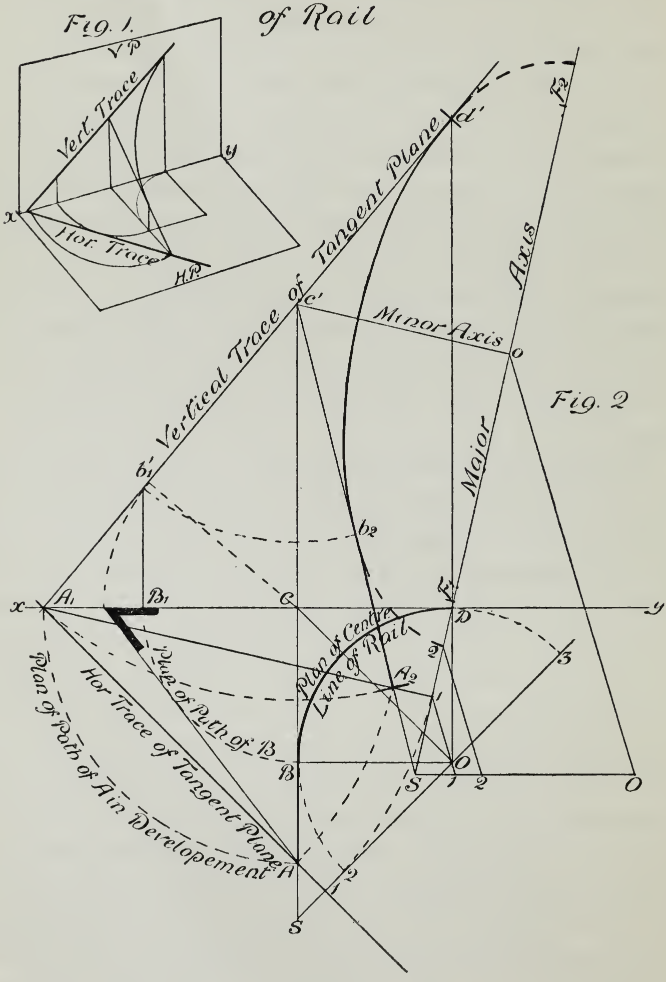
The above classification is necessary only for the

purpose of thoroughly understanding the causes which give rise to the necessity of employing one or two bevels, and bring about various changes in the figure.

In Chapter II. it was explained that the planes upon which the plans and elevations are projected stand at right angles to each other, and are termed the co-ordinate planes. These planes, for the convenience of drawing, are opened out into one—the plane of the paper—but as soon as the drawing is completed they are supposed to come up again into their proper positions at right angles to each other. For conventional purposes the line of intersection between them is known as the ground line or XY. It is by the use of these co-ordinate planes that the centre line of rail and other requirements of hand-railing are found.

To find the "centre line of rail."—Fig. 1, page 284, is a diagramatic representation of the problem shown at Fig. 2, and will assist the student to understand the latter geometrical method. AC and CD (Fig. 2, page 284) are the plans of the tangents of the rail passing over ABD. AB is the shank or straight part of the rail, and BD the curved portion, which, in this case, passes through an angle of 90°, or the fourth part of the circle. The heights of points A, B and D are known, also that of the intermediate point C (where the tangents cross). The tangent being in the vertical plane, $c'd'$ represents not only its true length, but a portion of the vertical trace of the plane containing it, and the tangent CB being turned back or developed into the vertical plane, its true length will be represented by $c'b_1'$. By producing $d'c'$ to the XY in point A_1 and joining it with A, the horizontal

Method of finding the Centre Line of Rail



and vertical traces of the plane containing the tangents are found. The plane containing these tangents is conveniently hinged to the vertical plane about the vertical trace, and thus falls into the plane of the paper. With A_1 as centre and with A_1A as radius, describe an arc. With c' as centre and with $c'A_1$ as radius, describe an arc cutting the first in A_2. Join A_1 with A_2 and c' with A_2, then the angle $d'c'A_2$ represents the real angle between the tangents, d' and b_2 being the tangent points to the elliptic curve.

For the purpose of completing the semi-ellipse, the plan of the "centre line of rail" is extended to form the semi-circle terminating at either end upon the plan of that steepest line in the plane which will pass through the central axis of the cylinder. This line is marked $S12O3$, and being the plan of the steepest line in the plane, it will of necessity be drawn at right angles to the horizontal trace of that plane.

That steepest line in the plane which passes through the axis of the cylinder will represent the major axis of the ellipse, and the minor axis will be represented by that horizontal line, lying in the plane, which passes through the axis of the cylinder and has its plan Oc parallel to the horizontal trace.

Upon the development of the inclined plane of the rail (centre line) draw the major axis at right angles to the development of the horizontal trace (A_1A_2 1) and through the point 1. Through c' draw $c'o$ representing the position of the minor axis, and therefore at right angles to the major axis. This line will be of the same length as its plan CO, and its divisions may be marked off direct from the plan.

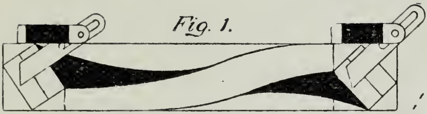
By producing the lower tangent ($c'B_2A_2$) to S, and the major axis to S, we have the half diagonal SO, which, when divided proportionately to its plan SO, will give us the major axis of the ellipse. From S, at the end of the half diagonal, set off the line S 1,2,0 at any angle and join its end 0 with the like point O of the half diagonal. Draw 2,2 and 1,1 parallel to 0,0; then 2,0 on the half diagonal will represent the semi-major axis.

The student, having the major and minor axis, will now be able to complete the elliptic curve, but must be careful to secure that the tangent points d' and b_2 are correct. The real length of the shank or straight portion is represented by the line b_2A_2.

The bevels required to be applied to the ends of the rails are represented by the angles contained between the inclined plane of the centre line of rail and the tangent planes. It will sometimes be found that the bevels are alike for both ends; the case represented on page 290 is an example, only one bevel being required.

To obtain the bevel.—The angle between the two planes is measured by a plane mutually perpendicular to the first two, and such planes standing at right angles to two others must have their horizontal traces at right angles to the plan of the line of intersection. In this case (page 284) the plan of the line of intersection is in the XY, and c, A is at right angles to it. We therefore select this line as the horizontal trace of the third plane, and set up cb'_1 at right angles to the line of intersection (the vertical trace of the plane). Now, by bringing down cb_1' into the same plane as cA, and completing the right-angled

Fig. 1.



Square Rail in Plank.

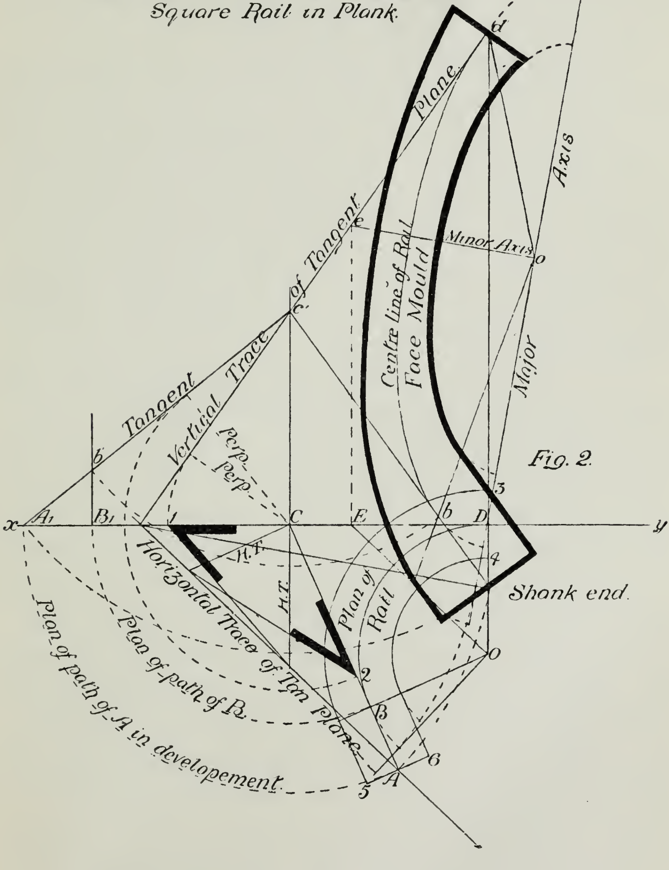


Fig. 2.

triangle we have the bevel or angle between the planes.

To find the Face-Mould.—For this purpose, another example has been selected, page 287, a rail of the second class, in which the plan of the rail extends beyond the quadrant of the circle; the tangents, therefore, contain an angle less than 90°.

The only points of importance in the diagram on page 287 that differ from that on page 290 is the fact that the tangents are unequally inclined, and the horizontal line lying in the plane and passing through the axis *O* does not pass through the point where the tangents cross. To the student who is able to successfully master the previous diagram this will not be a great difficulty, as *E* will have its elevation *e′* in its tangent immediately above it.

OE is the plan contained in the minor axis, and, being a horizontal line, represents its true length. When the major axis is drawn, *e′o* is drawn at right angle to it, and the points representing the minor axis taken directly from the plan. The major axis is divided similarly to the last example, six focal points being necessary instead of two. When the three ellipses are found, the butt ends of the rail are drawn at right angle to the centre tangent lines, and through the tangent points *d′b*. It is most essential, when taking up the face-mould, to take up the tangents to the "centre line of rail," also the position of the minor axis, as the rail at this point will be parallel to the face of the plank.

Two methods are practised for the cutting of the rail from the plank, and are described as follows:

"Square Cut" Method.—This is the most economi-

cal method of cutting the rail from the plank ; the saw passes at right angles to, or square with, the surface of the plank, hence its name (Fig. 3, page 290).

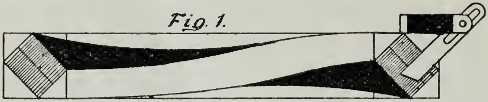
"Bevel Cut" Method.—This is the name given to the method of cutting the rail obliquely from the plank (see Fig. 4, page 290). When the cut passes at a very acute angle with the face of the plank, a great waste of material is the result, and although it is considered to be the most direct method, preference is given to the "square cut."

Fig. 2, page 290, is given to illustrate the method of obtaining the face-mould and bevel in a case where the plan of tangents is at an acute angle and the tangents equally inclined (one bevel only being required). The lettering has, as far as possible, been kept alike in the two examples, so that this example may be the more readily followed.

To decide the thickness of plank required for a rail: Take the section of a rail and turn it through an angle represented by the steepest pitched bevel ; draw parallel lines tangential to the curve at the top and bottom ; the distance between these parallels will represent the thickness of plank required.

Application of the Face-Mould.—The face-mould having been obtained, and the thickness of the plank decided, place the face-mould upon the plank, and mark the butt ends of the mould, also its centre lines; the ends are now ready to be cut. At this point the butt joints should be truly squared with the tangents ; this is accomplished by placing the stock of the square to the ends of the material, and so adjusting the ends until the blade of the square coincides with the tangent lines. The ends, which must

Fig. 1.



Square Rail in Plank

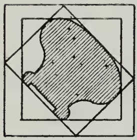


Fig. 3.

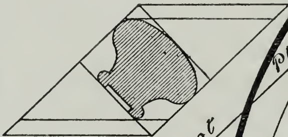


Fig. 4

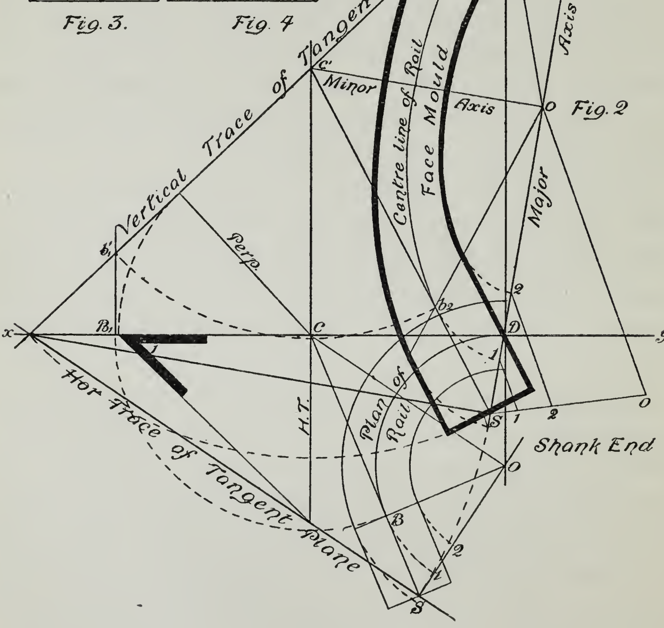


Fig. 2

also be squared with the face of the plank, must now be considered finished as regards their planes and should not be subsequently altered, as the least alteration here is likely to lead to greatly increased errors in the pitch of the rail. The face-mould more strictly belonging to the centre of the rail, the tangents should be squared over to the centres of the ends. These points having been obtained, the bevels are applied and the new positions for the top and bottom tangents are obtained. The face-mould now requires to be moved along until the tangents of the mould correspond with the new positions of the tangents on the plank; the outline of the rail may then be pencilled upon the plank.

To Construct the Outline of Scroll to any Diameter (Fig. 1, page 292).—Having decided the width *AB*, divide it into eight equal parts. At *A* let fall a perpendicular equal to one-eighth of *AB*. Join *BD*, and from *C* let fall a perpendicular to it, cutting it in *E*. With *C* as centre and *CE* as radius, describe an arc cutting *AB* in point 1, the centre of the first quadrant. Draw 1*F* perpendicular to *AB*, and describe the quadrant *BF*. Through *D*, draw *a* parallel to *AB*, intersecting 1*F* in point 2, the centre of the second quadrant. From *F* erect the perpendicular *F*, 0 upon *BD*; point 0 is the centre of the spiral. Join 1, 0, and produce, intersecting *D*2 in 3, the centre of the third quadrant. From 3 set up a perpendicular to *D*2, and with 3 as centre and 3*D* as radius, describe the third quadrant. Join 2, 0 and produce to intersect 3*H* in 4, the centre of the fourth quadrant. Draw 4*J* perpendicular to 4*H* and equal to it in length. With 4 as centre and

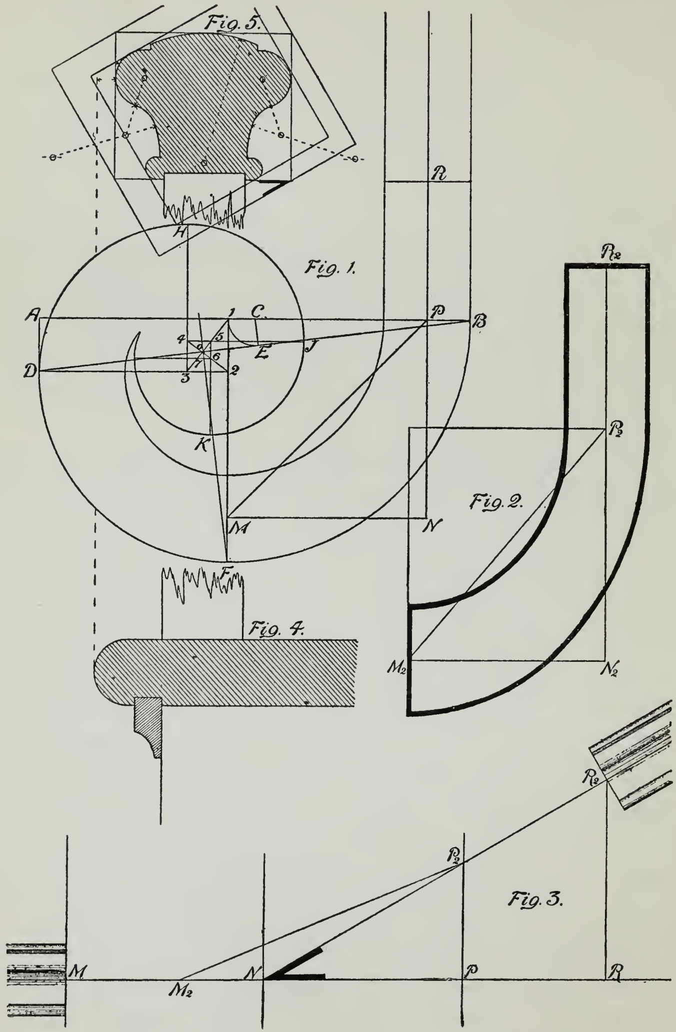


Fig. 5.
Fig. 1.
Fig. 2.
Fig. 4.
Fig. 3.
A
B
C.
D
E
F
H
J
K
M
N
P
R
M2
N2
P2
R2
1
2
3
4
5
6
7

$4H$ as radius, complete the fourth quadrant. The remaining centres may be found as follows: The diagonals 1, 3 and 2, 4 cut the perpendiculars $4J$ and $5K$ in points 5, 6, 7, etc., but beyond this it is seldom necessary to go. The inner margin of the rail is struck from the same centre as the outer, and at a distance from the latter equal to the width of the rail.

To find the Face-Mould for the Shank (Fig. 2, page 292).—This rail comes under the first class, having one of the tangents horizontal. The tangents to the centre line of rail are represented in plan at Fig. 1 by the lines LM and NP. The shank extends to the point R in plan. Fig. 3 represents a development of the lines in order to obtain their true lengths, MNP and R being of the same lengths as the corresponding lines of Fig. 1. RNR_2 represent the pitch of the stairs, similar in shape to the outline of the "pitch-board." In order to obtain the true length of the inclined tangent NP_2R_2, set up over the plan the respective heights of these points as obtained by the "pitch-board"; the hypotenuse of the right-angled triangle will give it its true length. The real angle between the tangents can here be obtained by inspection, and, as in all cases of the first class, will be found to be a right angle. MN and P_2, being set up in their correct positions, will represent the semi-minor and semi-major axes of the ellipse which may now be drawn. The increased width of rail at the butt end is due to the inclination of the plank, and may be found by setting the true width of the rail along the horizontal line NP (Fig. 3), and from the extremities set up the perpendiculars intersecting the inclined line

NP_2; the portion intercepted between the tops of the perpendiculars represents the increased width.

Easing the Rail.—It is usual in cases similar to the last to allow the shank portion of the scroll to take a more gradual change as it joins the scroll; this is accomplished by cutting the scroll out of material $\frac{1}{2}$ in. thicker than the rail, so that the moulded scroll can be formed to rise to the extent of $\frac{1}{2}$ in. as it approaches the shank piece. Fig. 4 represents the relative position of the end of the tread, with respect to the hand-rail above. An enlarged section of the rail is shown at Fig. 5, in order to illustrate how much material may be saved by working close to the section of rail. It is not advisable that the student should attempt this in the earlier stages of the work as it is likely to lead to mistakes, but to work his twisted rail first to the rectangular section, and then to mould it if necessary.

APPENDIX A.

SYLLABUS.

(From the Programme of the City and Guilds of London Institute.)

The Preliminary Examination will include questions founded on the following subjects:

1. British and metric systems of units of length, area, and volume.

2. Division of straight line into parts, and elementary problems in practical plane geometry. Construction and use of scales.

3. Construction of polygons as used in setting out a templet or mould for lantern lights and roofs of turrets, etc.

4. Area of plane figures. Construction of oblong equal in area to any irregular figure bounded by straight lines, and of not more than eight sides. Calculation of area of floors, walls, gables, and roof surfaces.

5. Properties of circle as applied to the setting out of circular arches and simple mouldings. Measurement of relation of circumference of circle to diameter, arcs, chords, etc.

6. The practical setting out of simple pieces of joinery, such as door-frames, king-posts, and of simple plane figures, including circular, elliptic and other curves, showing tangent and normals of arches and centering.

7. Measurement of bulk of simple solid figures, such as cube, prism, pyramid, cylinder, cone and sphere, and parts of the same.

8. Construction of plan elevation and section of simple solids. Representation in oblique and isometrical projection of solid figures, and also of the simple joints, such as housing, mortise and tenon, halving, etc.

9. Graphic methods of representing and measuring the stress in a simple truss. Simple experiments on bending and testing strength of beams. Principle of parallelogram and triangle of forces, and simple problems thereof.

10. Simple mechanical contrivances, such as lever, pulley, wedge, and screw. Problems illustrating their uses.

11. Practical determination of densities of different woods.

12. The principal tools used in carpentry and joinery, their names, shapes, uses, etc.

13. The more common woods used in carpentry and joinery.

ORDINARY GRADE.

In addition to the foregoing, candidates in the Ordinary Grade are expected to know the following subjects:

1. Nature and properties of the various kinds of wood used in carpentry and joinery, with the ports or places from which they are obtained. Methods of seasoning and preservation of timber. Strength of timber. Mode of planning and converting materials, so as to avoid waste and shrinkage, and obtain the maximum strength or stiffness.

2. Tools, their names, shapes, uses, etc. Labour-saving machinery.

3. Mechanical drawing as applied to carpentry and joinery. Drawings, full-size, showing shoulder-lines, etc.,

on the material before it is cut; and the various joints in carpentry and joinery. Setting out rods. Working drawings of panelled and framed and braced doors, door frames and casings, double hung sashes, sliding and hanging shutters, French casements, folding shutters, and boxings, rebates or linings for swing doors, etc.

4. A general knowledge of the proportions of stiles, rails, muntins, etc., in doors and windows, heights of rails in doors to suit knobs or latches, the usual sizes of doors, windows, etc., and of the kind of material and strength to be used.

5. Mouldings, their forms and names. Intersection of mouldings at different angles, also of straight and circular mouldings. Enlarging and diminishing mouldings. Lines for determining the sections of moulded bars and hip-rafters in skylights and lanterns. Method of determining the true section of raking mouldings over square or oblique plans, also when the given moulding is on the rake.

6. Bevels. Finding bevels for hip-rafters, jack-rafters, purlins, splayed linings, raking mouldings, and oblique work generally. Also a knowledge of the method employed to place bevel lines direct upon the work, without making a drawing of the same.

7. Newel and geometrical stairs. Proportion of riser and tread. General planning of stairs to clear windows, and other obstacles, and to obtain proper head room. Method of finding the proper position of winders and diminished fliers. General construction, and methods of support.

8. Mechanical principles. The principles required in framing roof trusses, timber partitions, trussed girders, bracing large doors, gates, etc. Drawings to scale of the same, showing the comparative strain in different parts, by means of graphic statics.

9. Methods of strengthening beams and girders by "flitching" and "trussing," etc. How wood roof trusses are acted upon by cambering the tie-beam, and the motive for cambering. Different methods of shoring. Flying and raking shores.

10. Joints. Mortise and tenon, the proportion tenons should bear to the thickness and width of material. The proportion of the parts of the tusk tenon, the position of mortises with regard to the neutral axis. Joints for oblique timbers, position of the shoulder with regard to the direction of the strain. Trimming round voids in roofs, floors, etc. Different methods of scarfing. Proper position, and kind of straps and bolts used to secure joints.

11. Hinges, various kinds of, and modes of applying them. Centre-pin joint, back-flap, rule-joints, etc. Working drawings, showing the path of different parts of the work so as to obtain clearance, etc.

12. A general knowledge of the use of weather boards, water bars, throating, etc., for external work. Particular attention should be paid to the form of joints and manner of hanging French casements and skylights.

13. Plumbing and slating. Preparing and fixing flashings, tilting pieces, forming drips, rolls, cistern heads, etc., for plumber and slater, construction of flats for lead and zinc—also preparing and fixing angle beads, grounds, etc., for plasterer.

HONOURS GRADE.

For the Honours Examination candidates must have passed in a previous year in the Ordinary Grade.

The Examination will be Written and Practical.

(1) *Written Examination.*—Advanced questions on some of the preceding subjects, and in addition a knowledge will be required of:

1. The various methods of constructing centres for segmental, elliptical, parabolic and other arches, showing the direction of the joint lines of the arch. Fixing and striking large centres.
2. Different forms of scaffolding, staging, and gantries, and their construction.
3. Circular work. Method employed to bend boards, ribs, or mouldings round circular work, by kerfing, grooving, steaming, etc. Moulds and bevels required for soffits in straight and circular walls—also for ribs in groins, domes, and niches, circle upon circle, etc.
4. Hand-railing. The proper height of hand-rails over fliers, winders, and round landings. Method of describing hand-rail scrolls. The theory and use of tangent planes and tangent lines, as employed in the tangent system of hand-railing. Method of determining the position of the face-mould plane, to pass through three points in the central line of rails—the moulds, bevels, length of balusters, etc.
5. Construction of fittings for churches, shops and domestic work, pews and stalls, shop fronts and cases, tables, fitments for butler's pantry, housekeeper's room, etc.

(2) *Drawing.*—Drawing to scale from data furnished by the Examiner.

(3) *Practical Work.*—Each candidate will be required, during the year preceding the Examination, to design and execute in suitable material an original piece of work, and to forward the same to London (carriage paid) on or before April 23rd, together with a certificate signed by his employer, or by the class teacher and a member of the School Committee, stating that the work has been wholly executed by the candidate himself without assistance. The specimen

of work must be accompanied with a working drawing, with particulars of quantity and nature of materials used, and must be of such dimensions that it will fit into a box not larger than two cubic feet.

NOTE.—Specimens are preferred which are sufficiently large to show the practical work and are loosely "wedged up" so that they can be taken to pieces for examination. Candidates are advised if they select so large a subject that it must be made to a small scale, to make in addition portions to an enlarged scale, showing the construction.

The candidates are advised to affix a price to their models if they wish to sell them, as the Examiner is authorized to recommend for purchase to the Worshipful Company of Carpenters any work he considers of especial merit.

Full Technological Certificate.—A Provisional Certificate will be granted on the results of the above Examination. For the full Technological Certificate in the Ordinary Grade, the candidate who is not otherwise qualified will also be required to have passed the Science and Art Department's Examination in the Elementary Stage at least; and for the full Certificate in the Honours Grade, in the Advanced Stage at least, in *two* of the following Science subjects:

I. Practical, Plane, and Solid Geometry.
III. Building Construction.
VI. Theoretical Mechanics.
VII. Applied Mechanics.

Certificates showing that the candidate has passed the Elementary Examination of the Science and Art Department in Geometrical Drawing, as well as in Freehand or Model Drawing, will be accepted in lieu of one of the above Science subjects for the full Technological Certificate in either grade of the Examination.

APPENDIX B.

QUESTIONS

SET BY THE EXAMINATIONS DEPARTMENT OF THE CITY AND GUILDS OF LONDON INSTITUTE, 1897.

54. CARPENTRY AND JOINERY.

(PRELIMINARY EXAMINATION.)

Monday, May 3rd, 7 *to* 10.

INSTRUCTIONS.

No Certificates will be given to candidates on the results of this Preliminary Examination, but their successes will be notified.

Candidates may take the Ordinary Grade without having passed the Preliminary Examination ; or both Examinations may be taken in the same year.

The number of the question must be placed before the answer in the worked paper.

Not more than *ten* questions to be answered.

Three hours allowed for this Examination.

1. What is the difference between the decimal and duodecimal systems of measurement? Which is in ordinary use amongst carpenters and joiners in England? Convert 7149 from the decimal to the duodecimal scale. (30 *marks*)

2. Describe the best method you know of constructing a scale of feet and inches, and illustrate by making a scale of $1\frac{1}{2}$ inches to a foot. (32)

3. It is proposed to construct a hexagonal lantern-light

of 5 feet diameter. Draw an outline plan of same on a scale of $1\frac{1}{2}$ inches to a foot. (32)

4. The hall over which is the skylight referred to in previous question is also hexagonal, and has a diameter of 12 feet. What is the area of the floor? (34)

5. One side of this hall has a semicircular bay window the full width of side. Find the area of the floor of the bay. (34)

6. Show, by sketches, the manner in which the several conic sections are obtained from a cone. Give rules for approximately setting out an ellipse. (34)

7. A baulk of timber is 20 feet long, 15 inches by 15 inches at one end and 12 inches by 12 inches at the other. What would be its price at 2s. per foot cube? (32)

8. Make an isometrical drawing of a cylinder 3 inches in diameter and $1\frac{1}{2}$ inches deep, standing on its base. (36)

9. Draw in isometrical projection, quarter full size, the mortise and tenon to the bottom rail of a 2 inch door, the parts separated. (36)

10. Two forces of 16 and 63 lbs. act upon a point at right angles to each other; find their resultant. (34)

11. A king-post roof truss, 20 feet span and 10 feet in height, has a purlin on each side resting on the middle of principal rafters, under which are the struts. The load of each purlin is 5 cwt. Find, graphically, the strain on each part of the truss. (40)

12. A man sitting upon a board suspended from a single movable pulley pulls downwards at one end of a rope, which passes under the movable pulley and over a pulley fixed to a beam overhead, the other end of the rope being fixed to the same beam. What is the smallest proportion of his whole weight with which the man must pull in order to raise himself? (30)

13. If three cubes of wood, the first of fir 3 inches on the side, the second of oak 4 inches on the side, and the

third of mahogany 5 inches on the side, are placed before you, how would you determine the relative densities of the different woods? (32)

14. Give a short description of six ordinary tools used by the carpenter and joiner. (36)

15. What wood do you consider most suitable for (*a*) tie-beams, (*b*) floor joists, (*c*) floor boards, (*d*) panelling, (*e*) shop fronts, (*f*) hand-rails. (30)

16. Explain how you would distinguish between a good and a bad deal. (32)

54. CARPENTRY AND JOINERY.

Saturday, April 24th, 2.30 *to* 6.30.

INSTRUCTIONS.

The candidate must confine himself to one grade only, the Ordinary or Honours, and must state at the top of his paper of answers which grade he has selected. He must *not* answer questions in more than one grade.

If he has already passed in this subject, in the first class of the Ordinary Grade, he must select his questions from those of the Honours Grade.

The number of the question must be placed before the answer in the worked paper.

A sheet of drawing paper is supplied to each candidate.

Drawing instruments to be used in this Examination.

Not more than *nine* questions to be answered in either grade.

Four hours allowed for this paper.

The maximum number of marks obtainable is affixed to each question.

FULL TECHNOLOGICAL CERTIFICATE.—Qualifying Subjects. *See* page 300. For Ordinary Grade, two in the Elementary Stage; for Honours, two in the Advanced Stage, from the following:—

I. Practical, Plane, and Solid Geometry.
III. Building Construction.
VI. Theoretical Mechanics.
VII. Applied Mechanics.

A Certificate in Elementary Stage of Geometrical Drawing as well as in Freehand *or* Model Drawing, will serve in lieu of one Science subject for either grade.

Passing the Preliminary Examination will count as one subject.

ORDINARY GRADE.

Every candidate is required to attempt question No. 3, *and* AT LEAST *four other questions.*

1. Give sketches to illustrate how the cutting of timber affects its use, and state how you would prefer timber to be cut from the log, and why. (32 *marks*)

2. Describe the various processes through which deal should be passed before it can be considered thoroughly seasoned. (34)

3. State for what purposes the following tools are used: Firmer chisel, back saw, jack plane, router, side fillister, chariot plane. (36)

4. Give plan and section, $1\frac{1}{2}$ in. to a foot, of a lead gutter behind stone parapet, showing feet of rafters, outlet of gutters, etc., complete. (32)

5. It is required to cover a building 40 ft. wide with roof in one span and $\frac{1}{4}$ pitch. Give elevation of the truss you would use to scale 4 feet to an inch. (34)

6. Give enlarged details of joints to the foregoing roof in isometrical projection, showing the ironwork you would use. (36)

7. Draw section to scale, $1\frac{1}{2}$ in. to a foot, through a fire-place on first floor, showing the construction and trimming of the floor. (34)

8. Draw to a scale, $1\frac{1}{2}$ in. to a foot, plan and elevation of an angle tie and dragon piece, and show how you would obtain the bevels of hip-rafter. (32)

9. Give sketches of a centre for semicircular stone arch 20 ft. span, and describe the position and use of wedges. (35)

10. What must be the scantling of a fir beam to carry safely a distributed load of five tons over a span of 10 ft.? (36)

11. Draw plan and elevation to $\frac{1}{2}$ in. scale of $2\frac{1}{2}$ in. framed, ledged, and braced door, in two heights, with fan-light over and solid fir wrought, rebated and beaded frame in opening 4 ft. by 9 ft. (34)

12. Draw plan and elevation to $\frac{1}{2}$ in. scale of a pair of $2\frac{1}{4}$ in. folding doors, each leaf five-panel bolection moulded with raised (or fielded) panels. Size of opening 6 ft. by 7 ft. 6 in. (34)

13. Show the linings and finishings, with details of grounds and backings, necessary to the above door in a 14 in. wall. (34)

14. Draw plan and section to scale, $1\frac{1}{2}$ in. to a foot, of a three-light casement with solid frame and mullions. Size of opening 5 ft. 6 in. by 3 ft. Give section through sill $\frac{1}{4}$ full size. (36)

15. Draw to a scale, $\frac{1}{2}$ in. to a foot, a newel staircase, with open well-hole 3 ft. 6 in. wide, in a hall 10 ft. wide. Height from floor to floor 12 ft. Show enlarged details of treads and risers. (36)

16. Give sketches $\frac{1}{4}$ full size of the following joints: Secret dovetail, double tenon and mortise, fox wedging, rule joint, meeting rail of double-hung sash, rebate and tongue. (36)

HONOURS GRADE.

Candidates for Honours must have previously passed in the Ordinary Grade, and must have already forwarded to the Institute the required specimen of their practical work.

Every candidate is required to attempt question No. 4, and AT LEAST *three other questions.*

1. Give a short description of the various European soft woods, and state the purpose for which each is best adapted. (32)

2. Give some account of dry rot, and the situations in which it is to be expected. What signs would lead you to believe that dry rot exists in the timbers of a building? What is to be done when dry rot is discovered? (35)

3. Describe the three best preservative processes (other than seasoning) with which you are acquainted, and state their value in increasing the durability of timber. (30)

4. Describe the construction, uses, cost of purchase, and expense of running *one* of the following machines: (*a*) General joiner; (*b*) planing machine; (*c*) spindle machine. (40)

5. Draw to scale, 1 in. to a foot, the foot of a hammer-beam truss, 40 ft. span and $\frac{1}{2}$ pitch; dot outline of tenons and show the bolts and straps. The hammer beam, with all work below it, and the ends of timber framed above, to be shown. (36)

6. Draw to scale, 1 in. to a foot, section through a ventilating turret, 6 ft. internal diameter, on the roof mentioned above, and show how you would frame it to the roof. (36)

7. Give elevation to scale, $\frac{1}{4}$ in. to a foot, of a quarter partition, 18 ft. wide and 24 ft. high, running through two storeys and self-supporting over the ground floor. On the first floor is a central doorway 6 ft. 6 in. wide by 7 ft. 6 in. high; on the second floor is a doorway 3 ft. wide and 6 ft. 6 in. high, 3 ft. 6 in. from one side wall; and another 4 ft. wide and 6 ft. 6 in. high, 2 ft. from the other wall. Give details of joints; show all ironwork and figure scantlings. (30)

8. Draw elevation and section to scale, $\frac{1}{4}$ in. to a foot, showing construction of a gantry over pavement 10 ft. wide and with staging 12 ft. from ground. (34)

9. Draw plan and section to scale, $\frac{1}{2}$ in. to a foot, of a shop front, showing arrangement for giving light to basement. Frontage, 18 ft.; height from floor to ceiling, 13 ft. (35)

10. Two houses of 18 ft. frontage each in a terrace have been pulled down, and shoring is required for supporting the adjoining houses on each side. Sketch to scale, $\frac{1}{8}$ in. to a foot, the shoring you would construct, and give scantlings and details of the joints. (32)

11. Give a description of not more than *six* hard woods with which you are acquainted, stating their nature, uses, cost, and the relative difficulty of working as compared with first quality yellow Baltic deal. (36)

12. Describe fully how you would set out a moulded hand-rail to a geometrical staircase which has ten winders, the well-hole being 2 ft. in the clear and the risers each 6 in. high. (38)

13. The staircase above mentioned has a veneered string. Work out to a large scale the development of the veneer round the well-hole, and show by dotted lines the construction. (36)

14. A niche segmental on plan, and 5 ft. wide across the front, has a domical head, semicircular on elevation. Show by sketches to scale, 1 in. to a foot, how you would construct the domical head, and give rules for finding curves of ribs and bevels of ends. (32)

15. Give a plan to scale, $\frac{1}{2}$ in. to a foot, of a butler's pantry, 10 ft. by 8 ft. and 10 ft. 6 in. high, showing the fittings necessary, and give details to scale of, $1\frac{1}{2}$ in. to a foot, of one of the fittings. (34)

16. Draw to scale, of $\frac{1}{2}$ in. to a foot, a lantern light, elliptical on plan, 7 ft. long, 4 ft. wide, and 3 ft. 6 in. high, internal dimensions. Show how you would get cuts or bevels of bars at top and bottom. (34)

1898.

PRELIMINARY EXAMINATION.

Monday, May 9th, 7 to 10.

1. Is the method of measuring in the carpenters' trade decimal or duodecimal? How would you convert from one system to the other? (36 *marks*)

2. Construct a plain scale to read 2 inches to 1 foot. (30)

3. Describe the method of inscribing in a circle any regular polygon. On a given line 2 inches long construct a pentagon. (30)

4. Make an irregular heptagon, and reduce the same to an oblong of equal area. (34)

5. The chord of a circle is 12 feet; the rise in the segment is 2 feet. Find the radius of the circle by figures. (35)

6. Set out a circular-headed door frame, inside measurement 4 feet, the door 2 inches thick. Transome with fanlight over. (38)

7. What is the cubical contents of half a regular hexagonal pyramid of 2 feet edge and 5 feet high? (37)

8. Draw the plan and elevation of a hexagonal prism of $1\frac{1}{2}$-inch edge at ends and 3-inch axis, when the axis is horizontal but inclined to the plane of elevation at 40°. Make the section of this prism, when cut by a plane, parallel to the plane of elevation. (38)

9. Make isometric or oblique drawings of the following joints, and figure their dimensions: "Haunched," "tenon joint," "grooved and tongued," and "common dovetail." (32)

10. The handle of a mortising machine is 2 feet long. How much more pressure would you be able to exert, applying the same force, if the handle were made 1 foot longer? (38)

11. (*a*) Describe the difference between the teeth of a ripping saw and those of a dovetail saw, and give the reasons for their respective shapes. (*b*) What bit would you use to bore a $\frac{1}{2}$-inch hole into the end grain of a piece of timber? (38)

12. Describe the characteristics and uses of the principal conifer timbers. (40)

ORDINARY GRADE.

Not more than *nine* questions are required to be answered.

1. Write a brief description of oak, teak, and yellow deal, and state the purposes for which they are used. Give the principal market firms and ports of shipment. (32 *marks*)

2. Why is the iron of a shoulder plane reversed, as compared with a jack plane? Why should the pitch of a moulding-plane iron be greater for hard wood than for soft wood? (35)

3. Make the elevation of rather more than half of a six-panelled door, 7 ft. 2 in. high and 3 ft. 2 in. wide; and a vertical section, scale 1 in. to the foot. All the parts should be fully dimensioned. Make to scale $\frac{1}{2}$ full size a detailed section through the panel and moulding. (36)

4. Make isometric drawings of the joint at the lock-rail of the door in the preceding question, and also of the joint at the bottom rail of the door, with double tenons. (32)

5. Make sections of the following mouldings: Cyma recta (Roman and Greek), Astragal torus (Roman and Greek), Cavetto (Roman and Greek), Ovolo (Roman and Greek). These drawings must be large enough to show the geometrical construction, and the working lines should be left in. (38)

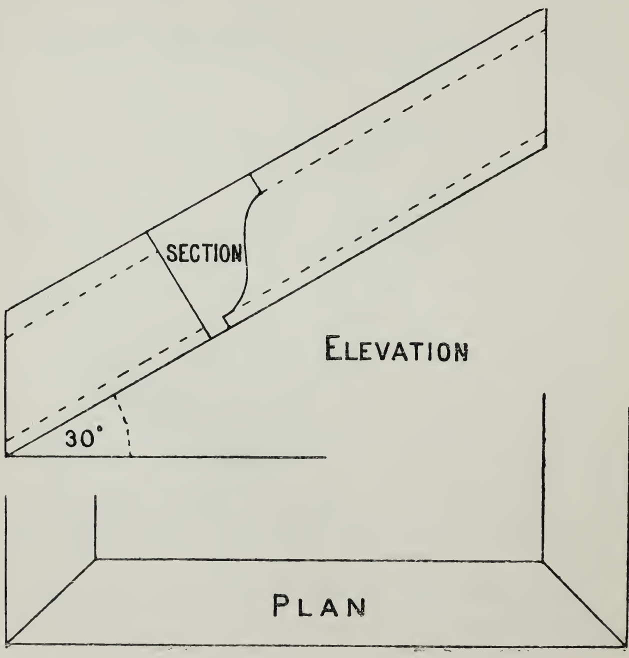
6. Make a half elevation to a scale of $\frac{1}{4}$ in. to the foot of a truss partition, 20 ft. wide, 15 ft. high, with a door-

way near each end. Illustrate by freehand sketches the joints, and the means you would employ in making and securing it. (40)

7. Draw a plan, to a scale of ½ in. to a foot, of a newel staircase, 3 ft. 6 in. wide; height, floor to floor, 12 ft.; in a hall 9 ft. wide. Explain the method of setting out this stair, and how you would determine the proper proportion of treads to risers. (40)

8. Make line diagrams and write the names of the parts of a collar-beam roof of 16 ft. span, and show by line diagrams the form of principal you would use for a 25 ft., 35 ft., and a 50 ft. span roof. Show the parts in compression by single lines, and those in tension by double lines. (36)

9.



The foregoing sketch is the plan and elevation of a moulding on the rake. Determine the method of working the two end pieces to intersect with it, and of obtaining the angles for mitreing it. (38)

10. What do you understand by strengthening beams and girders by means of flitching and trussing? Give sketches to illustrate. (32)

11. Show by sketch the different methods of scarfing, and state which are adapted for the different strains. (30)

12. Describe the following: Back flap, rule joint, and give illustrations of their use. (30)

13. Make a drawing of a small skylight, to be fixed in a flat roof, and give details to show how the weather is kept out. (32)

14. A room, 20 ft. by 15 ft., has a bay window, fireplace, and two doorways. Describe the method of fixing the grounds to receive the skirtings, architraves, etc. (34)

HONOURS GRADE.

N.B.—Candidates for the Honours Grade must have previously forwarded to the Institute a specimen of their practical work.

Candidates are expected to answer not less than five questions, but they may answer more.

1. A centre is required for an elliptical arch of stonework, having 25 ft. span and 10 ft. rise. Draw, to a scale of $\frac{1}{4}$ in. to the foot, such centering, and mark thereon scantlings of the timber. (34)

2. Describe and show in detail the mode of taking out the front wall of a ground storey to insert a shop front, with needful shoring. (38)

3. Give the best methods of seasoning timber, and the relative time required for the following: Yellow deal,

pitch pine, oak, black walnut, wainscot, and mahogany for joinery. What is meant by second seasoning, and how would you treat high-class joinery in going through the process? (32)

4. A niche is in shape a quarter of a sphere, and it is to be boarded so that the joints of the boards are horizontal when the boards are bent round. Show the geometrical method of setting out the boards. (36)

5. Draw half the horizontal section through an internal doorway, the wall being 18 in. thick. Show grounds, architraves, frame, jamb lining, and door $2\frac{1}{4}$ in. thick, with moulding on the solid and raised panels; scale, 2 in. to 1 foot. Write a brief description of making, fixing, and hanging such fittings in high-class work. (38)

6. A window has a 6-ft. opening. It is to be fitted with splayed folding boxing shutters. The soffit is framed. Write a brief description of the method of fixing the various parts. (32)

7. Make sketches of mouldings sufficiently clear to illustrate the character of the following: Greek, Roman, Norman and Decorated periods. Give sections of mouldings commonly used in various forms of joinery. (40)

8. Show how you would set out a rod for a window-frame fitted with a pair of French casements. (30)

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